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AUTOMATIC ELECTRIC

TECHNICAL JOURNAL

OCTOBER, 1961 VOL. 7, NO. 8

GENERAL SYSTEM

The Automatic Electric Technical Journal is published by
AUTOMATIC ELECTRIC LABORATORIES, INC., a subsidiary
of Automatic Electric Company, Northlake, Illinois, U.S.A.,

and the affiliated laboratories of

Leich Electric Company, Genoa, Illinois, U.S.A.
Lenkurt Electric Co., Inc., San Carlos, California, U.S.A.
Electronic Secretary Industries, Inc., Waukesha, Wisconsin, U.S.A.
Automatic Electric (Canada) Limited, Brockville, Ontario, Canada
Automatique Electrique, S.A., Antwerp, Belgium
Automatic Electric S.p.A., Milan, Italy
Marelli-Lenkurt S.p.A., Milan, Italy
Lenkurt Electric Co. of Canada, Ltd., North Burnaby, B. C., Canada

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AUTOMATIC ELECTRIC TECHNICAL JOURNAL

CONTENTS

A TELEPHONE ANSWERING SET FOR RESIDENTIAL SUBSCRIBERS ..... **Page 264**

Using the "bi-planar" system of recording, the new Model SP Electronic Secretary Telephone Answering Set permits 100% completion of calls to residences, at a cost commensurate with residential rates.

APARATO DE CONTESTACION AUTOMATICA PARA RESIDENCIAS

Merced al empleo del sistema de grabación "bi-planar", la nueva Secretaria Electrónica Modelo SP permite el servicio de contestación automática para residencias a un costo proporcionado a las tarifas domiciliarias.

APPAREIL TELEPHONIQUE A REPONSE ENREGISTREE POUR LES ABONNES DES QUARTIERS RESIDENTIELS

Utilisant le système "bi-planaire" d'enregistrement, le nouveau modèle SP de l'appareil "secrétaire électronique" permet de compléter à 100% les appels destinés aux quartiers résidentiels.

UN APPARECCHIO TELEFONICO A RISPOSTA REGISTRATA PER GLI ABBONATI DEI QUARTIERI RESIDENZIALI

Utilizzando il sistema di registrazione "bi-planare", il nuovo modello SP dell'apparecchio "segretaria elettronica" permette di completare il 100% delle chiamate destinate ai quartieri residenziali.

FIELD TRIAL OF A SATT SYSTEM WITH PPCS ..... **Page 270**

A report on a full-scale installation of toll-ticketing equipment to provide Person-to-Person, Collect, and Special-call service to more than 20,000 stations, through ten PPCS operator positions.

PRUEBA EN SITIO DE UN SISTEMA SATT CON SERVICIO PPCS

Informe que trata sobre un sistema integral de Teleselección Automática (SATT) para proporcionar Servicio de Persona a Persona, por Cobrar y de Llamadas Especiales (PPCS) a más de 20.000 teléfonos a través de diez posiciones de operadora.

ESSAI PRATIQUE D'UN SYSTEME SATT AVEC PPCS

Ce rapport est basé sur l'étude d'une installation réelle SATT (système automatique de tarifage interurbain) afin de fournir un service PPCS (de personne à personne, à recouvrement et avec appels spéciaux) à plus de 20.000 abonnées, grâce à dix positions d'operatrice PPCS.

MISURE PRATICHE DI UN SISTEMA SU SATT CON PPCS

Questo rapporto é basato sullo studio di una installazione reale SATT (sistema automatico di tariffazione interurbana) ai fini di permettere un servizio PPCS (da persona a persona, con pagamento da parte del chiamato, e con chiamata speciale) esteso a più di 20.000 utenti, grazie a dieci posti d'operatrice PPCS.

A "HIGH-DENSITY" CARRIER TELEPHONE SYSTEM ..... **Page 277**

Designed to coordinate with other systems and conform to CCITT recommendations, Lenkurt's Type 46A Carrier Telephone System is readily expansible to 600 channels, and provides alternate circuits for dependability.

SISTEMA TELEFONICO DE ONDA PORTADORA DE "ALTA DENSIDAD"

Sistema Telefónico de Onda Portadora Lenkurt Tipo 46A, proyectado para permitir la coordinación con otros sistemas de onda portadora. Cumple con las normas recomendadas por el CCITT. Puede ampliarse fácilmente hasta 600 canales y proporciona circuitos alternos para mayor seguridad funcional.

SYSTEME TELEPHONIQUE A COURANTS PORTEURS A GRANDE CAPACITE

Etudié pour l'interconnexion avec d'autres systèmes et se conformant aux recommendations du CCITT, le système Lenkurt Type 46A est facilement augmentable à 600 canaux et est pourvu de circuit alternés pour majeure sécurité.

SISTEMA TELEFONICO A FREQUENZA PORTANTE AD ALTA CAPACITA

Progettato per l'interconnessione con altri sistemi, e pienamente conforme con le raccomandazioni del CCITT, il sistema a frequenza portante Lenkurt 46A é facilmente estensibile per una capacità di 600 canali telefonici, ed impiega circuiti alternati ai fini di una più efficente sicurezza di servizio.

WALTER AXELSEN
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CONTENTS (Continued)

APPLYING THE AT-6 NEGATIVE-IMPEDANCE REPEATER ..... **Page 283**

Because the AT-6 Repeater differs fundamentally from previous negative-impedance repeaters, different techniques, described in this paper, are used in applying it to the telephone plant.

REPETIDOR AT-6 DE IMPEDANCIA NEGATIVA—SU APLICACION

Dado que el repetidor AT-6 difiere fundamentalmente de los repetidores de impedancia negativa anteriores, en su aplicación a las plantas telefónicas se emplean distintas técnicas, explicadas en detalle.

APPLICATIONS DU REPETEUR A IMPEDANCE NEGATIVE AT-6

Comme le répéteur AT-6 diffère profondément des répéteurs à impédance négative précédents, différentes techniques, décrites dans cette communication, sont utilisées pour son application aux réseaux téléphoniques.

APPLICAZIONE DEL RIPETITORE A IMPEDENZA NEGATIVA AT-6

Il ripetitore AT-6 differisce fondamentalmente dai precedenti ripetitori a impedenza negativa. Quindi tecniche differenti, descritte in questa comunicazione, vengono seguite nella loro applicazione alle reti telefoniche.

SELF-CONTAINED P-A-B-X SERVES 80 STATIONS ..... **Page 289**

Made up of standard units that can be ordered from stock, this Leich switchboard can be easily installed to provide a wide variety of services, and may be removed and re-used as necessary.

P-A-B-X ADAPTABLE DA SERVICIO A 80 TELEFONOS

Este cuadro conmutador Leich compuesto de unidades normalizadas, proporciona una extensa gama de servicios. Puede instalarse con suma facilidad, quitarse y reubicarse según se necesite.

UN P-A-B-X SERT 80 POSTES

Composé d'unités standard qu'on peut se procurer de stock, ce central Leich, d'installation facile, donne une grande variété de services; de plus, il peut être démonté puis ré-utilisé par la suite, suivant les besoins.

UN P-A-B-X PER 80 UTENTI

Costituito con unità standard che possono venire ordinate da magazzeno, questo centralino Leich di facile installazione provvede una grande varietà di servizi; inoltre puo' essere smontato e riutilizzato a piacere.

THE NEW AUTOMATIC TRUNK ROUTINER ..... **Page 297**

This routiner is especially valuable with automatic toll switching and Extended Area Service, for routine-testing local interoffice and intertoll trunks accessed from selector levels.

NUEVO RUTINADOR AUTOMATICO DE TRONCALES

Con la conmutación automática de llamadas de larga distancia, este rutinador resulta especialmente valioso para efectuar pruebas de rutina de líneas de enlace entre centrales o entre mesas interurbanas alcanzadas desde los niveles del selector.

NOUVEL APPAREIL D'ESSAI SYSTEMATIQUE DES LIGNES

Cet appareil est particulièrement indiqué pour les réseaux à commutation automatique interurbaine et à zone étendue, et pour l'essai systématique des lignes de jonction et des lignes interurbaines aboutissant à des niveaux de selecteurs.

IL NUOVO ROUTINER AUTOMATICO

Questo Routiner, particolarmente adatto per le reti di teleselezione automatica ed a zona estesa, permette di eseguire misure sistematiche sulle giunzioni locali ed interurbane direttamente connesse ai livelli dei selettori.

DATA TRANSMISSION THROUGH STROWGER AUTOMATIC OFFICES ..... **Page 301**

Tests conducted by transmitting digital data at a speed of 74.2 bits/sec (100 words/minute) through actual operating networks indicate that Strowger Automatic equipment is completely adequate for "slow speed" data transmission.

TRANSMISION DIGITAL POR CENTRALES AUTOMATICAS STROWGER

Las pruebas realizadas transmitiendo información digital a una velocidad de 74.2 bits/segundo (100 palabras/minuto) por redes telefónicas en funcionamiento, revelaron que el equipo automático Strowger es apropiado para la transmisión digital descrita en este artículo.

TRANSMISSION DE DONNEES A TRAVERS LES CENTRAUX AUTOMATIQUES STROWGER

Les essais faits sur la transmission de données digitales à la vitesse de 74.2 bits/seconde (100 mots/minute) à travers des réseaux réels prouvent que l'équipement automatique Strowger est plus que suffisant pour la transmission de données, ainsi qu'il est décrit dans cet article.

TRASMISSIONE DI DATI ATTRAVERSO LE CENTRALI AUTOMATICHE STROWGER

Misure effettuate mediante la trasmissione di dati in forma digitale con una velocità pari a 74.2 bits /sec. (100 parole/minuto) attraverso reti reali dimostrano che gli equipaggiamenti automatici Strowger sono perfettamente adeguati alla trasmissione di dati.

TELETYPEWRITER SWITCHING FOR A POLICE DEPARTMENT ..... **Page 306**

Facilities designed for the Chicago Police Department provide separate teletypewriter networks for administrative and for operations messages, with operator-controlled selection of receiving machines.

SISTEMA DE CONMUTACION DE TELEIMPRESORES PARA EL CUERPO DE POLICIA

Las instalaciones que han sido desarrolladas para la Jefatura de Policía de la Ciudad de Chicago, proporcionan redes separadas de teleimpresión para usos administrativos y para mensajes policíacos. La selección de las máquinas receptoras es controlada por operadoras.

SYSTEME DE COMMUTATION POUR TELEIMPRIMEURS UTILISE PAR LES SERVICES DE POLICE

Le système étudié pour la Police de Chicago prévoit des réseaux de téléimprimeurs pour les messages administratifs séparés de ceux des messages operationels, avec sélection des machines réceptrices sous le contrôle d'opératrices.

SISTEMA DI COMMUTAZIONE PER TELESCRIVENTI UTILIZZATO DAL DIPARTIMENTO DI POLIZIA

Il sistema appositamente sviluppato per il dipartimento di Polizia di Chicago prevede reti di telescriventi per messaggi amministrativi separate da quelle per messaggi operativi, con selezione delle macchine riceventi direttamente controllata dalle operatrici.

A TELEPHONE ANSWERING SET
For Residential Subscribers

By J. J. Zimmerman
Electronic Secretary Industries, Inc.

Automatic telephone answering has been developing commercially for about twelve years. During this period, most effort has been beamed at the obvious user—the dry-cleaner, the real-estate broker, the wholesale drug firm, the meat-packing house, or the business man whose occupation, by its very nature, required after-hours answering. Many of the foregoing applications call for medium- or heavy-duty operation of the equipment—some of them, for extended recording capacity of one to two hours or more—and these requirements have governed the designers of telephone answering sets.

Experience with telephone answering service in commercial applications has suggested to many

Figure 1. The Model SP "Bi-Planar" Answering Set was designed for residential use.

users the importance of *telephone call completion* to even the residential subscriber. They have learned that telephone service without answering service is incomplete, since the average telephone subscriber is not in a position to answer the telephone more than about twenty-five per cent of the time! People are frequently out in the back yard or otherwise busily engaged so that it is not convenient to answer the phone immediately. To complement regular residential telephone service and permit completion of 100% of telephone calls to residences, it would be necessary, however, to design an answering device that could be made available at a cost commensurate with residential telephone rates. Our work on this project has produced the Model SP ("Short-Play") Telephone Answering Set (Figure 1.).

Our approach to the problem was to analyze the needs and the requirements of the average residential or small-business subscriber. The "black box" specifications thus derived called for a machine that would take approximately twelve messages in one period of absence, the duration of each message to be approximately fifteen seconds. Facilities for the subscriber to record his own answering message were considered essential, since many different messages would be required and this would preclude the use of the professionally pre-recorded message. The ability of the machine to answer in the subscriber's own voice might also prove more appealing because of the less formal manner of residential telephone answering.

Our most formidable and challenging task was to produce a machine of this type for approximately half the selling price of the lowest-priced commercial telephone answering machine in our line — even though the commercial machine referred to does not include, as standard equipment, facilities for the subscriber to record his own answering messages. Since we felt that the greatest savings could be made by simplifying the mechanical assembly, much design effort was spent in that direction.

The "Bi-Planar" Principle

After weighing a large number of designs, a fixed-cycle machine, using a system of "bi-planar" recording, was chosen. The word "bi-planar" alludes to a method of recording on magnetically coated material in two planes at right angles to each other. To be more specific, the outgoing message is recorded on a strip of cushioned magnetic material laminated to the vertical flange of a phonograph-type turntable. The incoming messages are recorded in concentric circles on the flat or disc surface of the turntable. Each concen-

tric circle forms a channel or recording path, the "record and play-back" head starting from the outside edge of the turntable and moving inward to trace out recording channels 1-2-3 . . . up to 13.

Unlike most magnetic drum or disc devices, the tone arm of the "SP" set does not spirally scan the disc to effect a continuous recording, but rather steps across it, to form concentric recording paths. The stepping occurs at the end of each operating cycle and is accomplished by means of a cam-follower linkage on the underside of the turntable, driven by a stepping switch. In automatic operation, the machine disables itself when the last step is reached, so that further calls cannot be taken.

The original design of the "SP" set provided a mechanical cam system to effect starting, stopping, "midcycle shift", and transmission of signalling tones. This system has since evolved into an electrical arrangement using only one cam-operated switch that determines a home position on the turntable. The switching is performed by a combination of conventional relays with a self-homing ratchet relay.

The requirements established for the switching circuit were met as follows: A ringing relay, operating together with the telephone ringer, moves the turntable off standby position and seizes the telephone line. During the first revolution of the turntable, the outgoing message is delivered. As the turntable starts a second revolution, "midcycle shift" occurs, transmitting a signal tone to the telephone line (indicating that the calling party can begin recording) and switching the amplifier and heads so that incoming messages can be recorded.

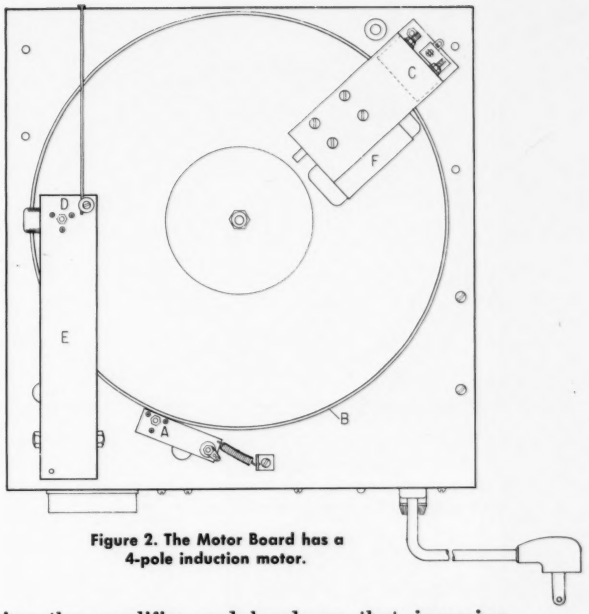


Figure 2. The Motor Board has a 4-pole induction motor.

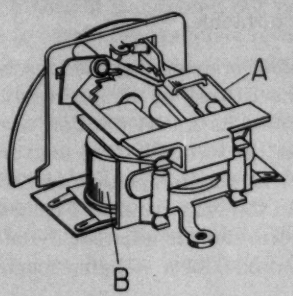
At the completion of the second revolution, switching occurs which:

(a) transmits a terminating tone
(b) shifts the tone arm
(c) releases the line-seizing relay

Mechanical Design

The working assembly of the Type SP machine may be broken down into three principal assemblies:

1. The Motor Board (the turntable).
2. The Electrical Switching Assembly,



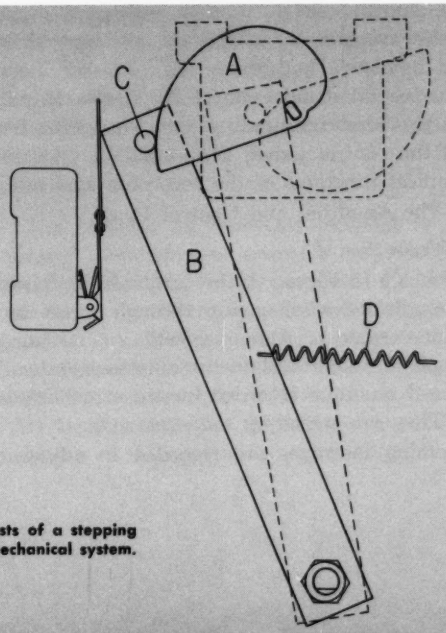


Figure 3. The Stepping cam consists of a stepping magnet, a reset magnet, and a mechanical system.

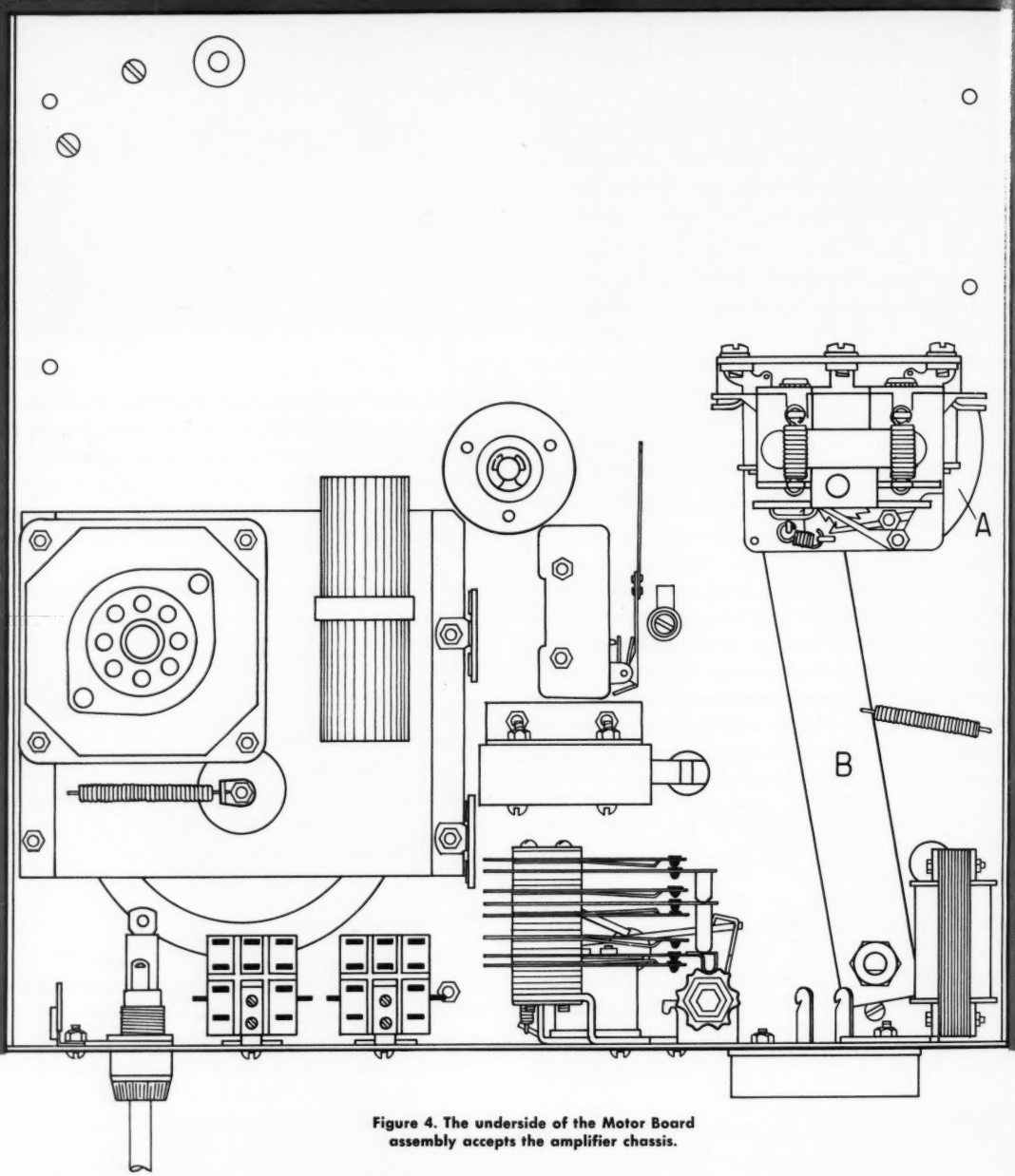


Figure 4. The underside of the Motor Board assembly accepts the amplifier chassis.

mounted on the underside of the Motor Board, which provides coordinating and sequencing between the control panel, the amplifier, and the mechanical functions of the recording system.

3. The Amplifier and Control Panel.

The Motor Board

As shown in Figure 2, the turntable is driven by a 4-pole induction motor, through a two-step reduction system. Announcement or outgoing messages are dictated into the out-message head (A) and are thus recorded on the rim surface (B). They are erased by the erase magnet (C).

Incoming messages are recorded in adjacent concentric circles or channels by record head (D) on tone arm (E). All incoming messages are erased simultaneously by energizing the erase magnet (F) with 115 volts ac during one revolution of the turntable.

The equivalent of rewinding the tape is accomplished on the SP set by simply resetting the tone arm (E) to its initial position toward the outside edge of the turntable. The tone arm steps automatically, at the completion of each automatic cycle, to the next channel. Figure 3 shows how the tone arm steps to adjacent channels. The stepper cam consists of a stepping magnet (A),

a reset magnet (B), and a mechanical system consisting of ratchet, lever, spring and pawl, to convert the reciprocating motion of the magnet armature to the rotary motion of the cam. Each time the cam advances against spring loading, it is held in that position by the engagement of the pawl in the ratchet wheel. The reset magnet on the stepper assembly pulls the pawl away from the ratchet, and allows the spring-loaded ratchet wheel and cam assembly to return to its starting position.

Referring now to Figure 4, we see that movement of cam (A) imparts a radial movement to tone arm follower arm (B), because of the engagement with the follower arm pin. The tone arm follows a path on the upper side of the turntable identical to that of the follower arm on the underside of the turntable. Thus a pulse of electrical current applied to the advance-magnet coil will step the tone arm to a position closer to the center of the turntable. Likewise, energization of the reset coil will release the pawl in the stepper assembly and allow the cam to return to a starting position. The tone-arm follower, spring-loaded by spring (D), will follow the cam back to its initial position. Thus, the tone arm will return to its starting point in one instantaneous motion; this is equivalent to rewinding a tape containing thirteen separate messages.

The starting position of the turntable is electrically indicated, for control purposes, by a switching operation which takes place when a bossed actuator at one position on the underside of the turntable (see Figure 5) operates a microswitch that, in turn, causes a secondary pulsing relay in the electrical control circuit to be operated. This raised section on the underside of the turntable will thus provide a homing position from which starting, stopping, and "midcycle shift" switching can be controlled.

From a control standpoint, our principal problem was to obtain two complete revolutions of the turntable for every complete cycle of operation. During the first revolution of the turntable, the announcement message is transmitted to the telephone line from the rim or vertical surface of the turntable. During the second revolution of each operating cycle, incoming messages are recorded onto the horizontal or disc surface of the turntable. At the completion of each automatic cycle, energy is supplied to the advance magnet of the stepping switch to cause the tone arm to step to the next adjacent channel.

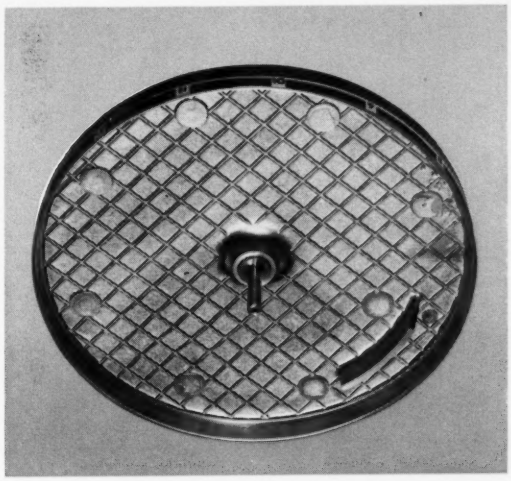


Figure 5. Underside of turntable has a projecting, cycling lobe.

General Features

In addition to the principal of "bi-planar" recording, other measures have been taken to provide functional efficiency at low cost. The methods of indicating the progress of outgoing dictation recording, as well as of incoming recordings, are examples of this.

The progress of dictation recording is indicated directly through a count-down window. The indicating device is a band of printed tape laminated to the rim of the turntable, just below the magnetic recording surface on the turntable rim. This tape not only tells the operator when to start dictating (by presenting a colored bar at the window opening), but as the table turns it actually counts down the seconds of remaining time for dictating; that is, 14 . . ., 13 . . ., 12 . . ., etc.

The "number of messages received or used" channel indicator (see cover) is another "direct approach" device. As the tone arm steps across the record an indicating pointer, attached to the front of the tone arm, likewise traverses a path across the face of a window. The indicator will show channel numbers 1-13 and then the letter "E", indicating the depletion of recording capacity.

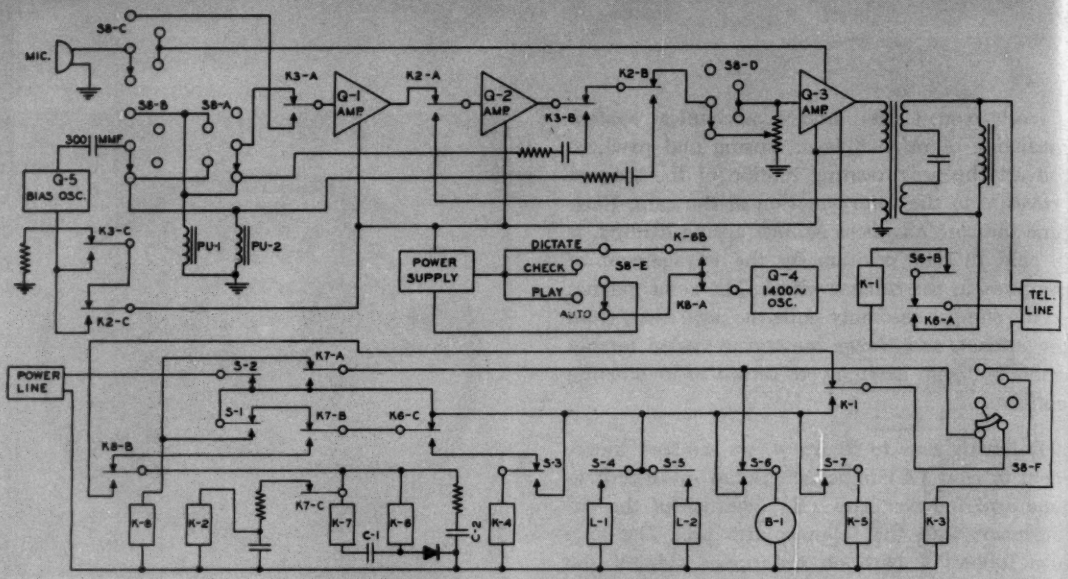


Figure 6. Block diagram.

Automatic Operation

To detail the automatic operation of the dictate record assembly, the essential switching elements (see Figure 6) must be listed:

K-1—the ringing relay
K-2—the incoming record relay (prepares the machine for recording messages of the calling party)
K-3—the dictate relay (permits the subscriber to dictate his own announcement message)
K-4—the advance coil of the stepping switch which indexes the tone arm
K-5—the reset coil of the stepping cam which returns the tone arm to the starting position
K-6—the line seizing relay
K-7—the ratchet relay (resets the contacts each time it is pulsed)
K-8—the pulsing relay (operates each time it is pulsed)
S-1—the homing cam switch (operates from a rise on the underside of the turntable—once for each revolution of the turntable)
S-2—the "OFF-ON" switch
S-3—the tone arm advance switch
S-4—the erase magnet switch (dictation message)
S-5—the erase magnet switch (incoming record)
S-6—the motor start switch
S-7—the tone arm reset switch
S-8—the function selector switch

Outgoing Announcement

To DICTATE the channel selector switch is placed in the dictate position and the microphone is inserted into the microphone jack. Starting switch S-6 is depressed momentarily, causing the motor to start and S-1 to close after the homing cam passes off the S-1 actuator. K-3 operates; K-3B connects the microphone to the input of its amplifier Q-1; K-3A connects the output of transistor Q-2 to dictate head PU-1; K-3C activates bias oscillator Q-5, by connecting it to the power supply. The channel selector connects the bias oscillator through a 300 mmf capacitor to the dictate head PU-1.

Checking the Announcement

To check his announcement message, the user places selector switch S-8 in the CHECK position. This connects PU-1 (the announcement head) to the input of Q-1. Another section of selector switch S-8 connects the output of Q-2 to Q-3, and still another section connects the output of Q-3 to the microphone jack for playback of the announcement message. Starting switch S-6 is depressed momentarily for one cycle of operation.

Incoming Message

When ringing current is applied to K-1 (the ringing relay) K-1 operates. Current flows through S-2 through K-1A, S-8F, S6 and turntable motor B1. B1 now drives the turntable. At this point, the homing cam switch S-1 closes, K-1 releases and K-8 operates. Current flows through S-1, K-7A, S-8F, K-1, K-8B, K-6 (the line load relay) thus seizing the telephone line and cutting off the ring. Current will also flow through K-7, but because of the blocking action of capacitor C-1 it will only be pulsed, and being a ratchet relay, will reset each time it is pulsed to its opposite switching position. The turntable is now running and the announcement message is being delivered.

At midcycle, the following switching sequence takes place:

The homing cam opens S-1 momentarily. K-8 releases but K-6 remains operated during the transit time of K-8B because of the discharge of C-1 and C-2. K-7A latches the motor. K-8A completes a return path to the tone oscillator, thus transmitting a signalling tone to the telephone line. After the turntable has moved far enough to carry the homing cam past S-1, S-1 again closes, K-8 operates, K-7 gets another pulse, K-6 is again latched through S-1, K-7A, S-8F, K-1 and K-8B. K-7C completes a path to K-2 (the incoming record relay); the turntable is now on its second revolution and the machine is prepared to record incoming messages. After the second complete revolution of the turntable, the homing cam again depresses S-1, opening it. This action causes K-8 to release. Because of the discharge time of C-1 and C-2, K-6 will remain operated during the transit time of K-8B. Current now flows through S-1, K-7B, K-6C, S-3, K-4, causing the tone arm to shift. C-1 and C-2 now discharge and K-6 releases, thus terminating an automatic cycle.

If K-7 (the ratchet relay) gets out of synchronization, current will be fed through K-7B, K-6C and K-8B, thus pulsing K-7 and resetting it for another call. This sequence makes the ratchet relay self-synchronizing.

Playback of Incoming Messages:

To playback recorded incoming messages, the selector is placed in PLAY position. This action connects the output of the playing head to the input of Q-1, connects stages 2 and 3 together, and connects the output of Q-3 to the microphone jack. Now the start button is depressed momentarily for one cycle of playback operation. To reset the playback tone arm to the first message, the reset switch S-7 is pressed momentarily. Then, for each message, the tone arm advance switch is operated to select the channel, and the start switch S-6 is operated to obtain a cycle of playback operation.

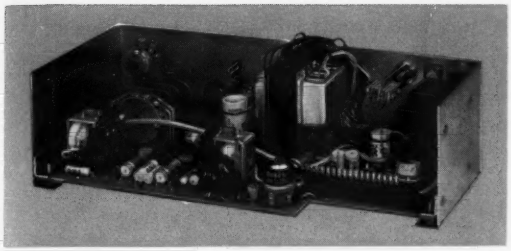


Figure 7. Amplifier and control assembly show plug-in components and ease of maintenance.

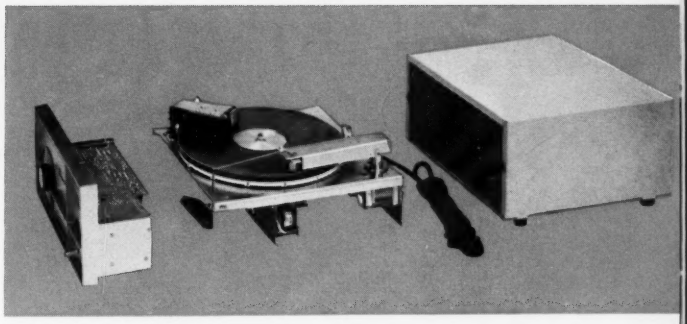


Figure 8. The exploded view of the machine assembly shows the control and electrical assembly, the mechanical assembly and the cabinet.

The main electronic assembly (Figure 7) is a printed circuit board amplifier and oscillator, on which even difficult components such as the rotary switch and the relays are inserted into the printed pattern. This saves many steps in assembly and wiring, and results in greater consistency in performance.

As may be seen from Figure 8 the SP set employs a unit type of construction, in which any one principal subassembly can be removed from the main assembly without unwiring or using involved disassembly techniques. The front control panel and amplifier assembly can be electrically and mechanically attached to the motor board assembly by inserting a plug and two screws. The entire combination can then be pushed into a tube-like enclosure and retained therein by two lead pins, which fit into a flange on the front of the cabinet enclosure and are held by two retaining bolts in the rear of the assembly.

Conclusion

We feel that the Model SP Telephone Answering Set in its present form complies with most of the original design objectives:

(a) It provides a basically simple and rugged mechanical assembly that will withstand 10-15 years of use without extensive service problems.

(b) It contains a very simple electromechanical control system.

(c) It includes simple and trouble-free electronic circuitry, made possible by the use of transistors and printed-circuit techniques.

(d) It can be offered to operating telephone systems at a price commensurate with generally prevailing rates for residential service.

Joseph J. Zimmerman, inventor of the Electronic Secretary, graduated from Marquette University in 1935 with a Bachelor of Science degree in Electrical Engineering. He worked for a time with Western Electric and Ilg Ventilating in Chicago. During the War, he was in the Army Signal Corps, did graduate work at Ohio State, and served in England, France, New Guinea and the Philippines. He returned to civilian life in 1945 and to electrical temperature control engineering. In May, 1949, he and George Danner organized Electronic Secretary Industries, Inc., to manufacture and sell the device he had developed. He is Vice President and Chief Engineer of ESI.

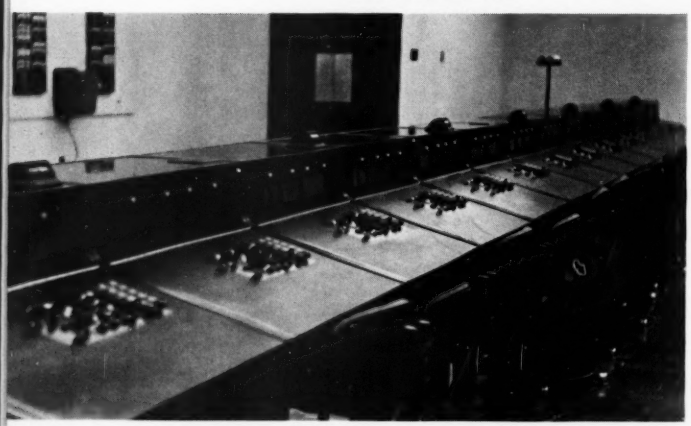
FIELD TRIAL OF A SATT SYSTEM WITH PPCS

By R. B. King
Automatic Electric Laboratories, Inc.

The first Strowger Automatic Toll Ticketing (SATT) system with facilities for handling Person-to-Person, Collect, and Special calls (PPCS) was put in service on March 4, 1961, at Pomona, California—a General Telephone Company of California exchange. For the first two weeks, operation of the PPCS was on a shakedown basis with limited traffic; then the service was opened up to all of the more than 20,000 stations in this exchange, except the paystations. Although frequently referred to as the Pomona PPCS trial, the installation is arranged for service through ten operator positions (see Figure 1) and is thus a full scale installation — probably the first in this country outside the Bell System.*

Pomona lies about midway between Los Angeles and San Bernardino. The heavy traffic to Los Angeles is "long-haul" — that is, 10-digit rather than 7-digit. The Pacific Telephone and Telegraph Company operates a toll board at Pomona which handles the manual toll and dial service assistance (DSA) calls. Local switching is provided by the General Telephone Company of California office, and special arrangements have been made between the two companies to provide SATT in this office, for the customer-dialed toll calls. Station-to-Station Paid Calls are handled by a Type 53 SATT system with long-haul facilities as previously described.**

Figure 1. Part of the cordless PPCS board installed at Pomona, California.



The general nature of the services required for PPCS has already been discussed.*** The normal practice in adding PPCS to an existing SATT system will be to arrange for joint use of as much of the *existing* equipment as practicable. For Pomona, however, in order to get the trial started as quickly as possible, the PPCS services were provided by separate equipment. operating in parallel with the Type 53 SATT system. This obviated the need for any major rebuilding of the system already in operation. To further hasten the completion of the project, the time required for new circuit development and equipment design was reduced by utilizing for Pomona a few

*Special Positions for Person-to-Person, Collect, and Credit Card Calls—L. Freericks. Electrical Engineering Vol. 79, No. 10, October, 1960, pp. 814-817.

**Extension of Type A SATT Systems to Direct Distance Dialing. W. A. Rust. Automatic Electric Technical Journal Vol. 7, No. 5, January, 1961, pp. 184-193.

***Expanding the Scope of DDD Service. Facilities to serve Person, Collect, and Special Calls. F. L. Kahn, Automatic Electric Technical Journal Vol. 7, No. 4, October, 1960, pp. 126-132.

of the actual circuits used in the Type 59 SATT system.*

A new feature of the PPCS equipment is the display unit on each switchboard position (see Figure 2) which contains ten digit-display devices of the rear-projection type. Through this unit the PPCS operator receives most of the information she needs for handling each call.

The relation between the existing Type 53 SATT system at Pomona and the added PPCS equipment is shown in Figure 3. The upper portion of this block diagram (page 272) shows the Type 53 system as arranged to handle long-haul traffic; the additional circuits required for PPCS are shown on page 273.

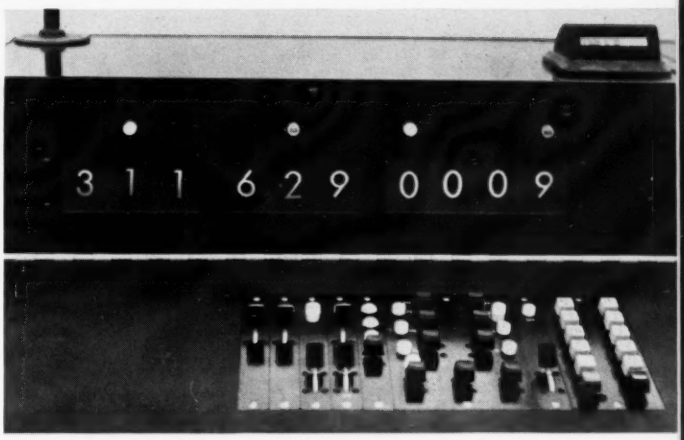


Figure 2. Digit-display panel at PPCS operators position shows either called number, or calling number and ticketer number, under key control.

Operation

To make a PPCS call by Direct Distance Dialing (DDD), the subscriber prefixes a zero to the called number. The Director register-sender normally interprets a zero as a request for DSA or CLR service. At Pomona, a timer has been added to the Director register-senders so there will be a few seconds delay, after a zero is received, before the call is routed to an operator. If additional digits start to come in during this period, the call is not routed to an operator; instead, the called number is registered and a PPCS "class" indication is provided for the translator, so the call will be routed to the appropriate group of PPCS ticketers—either 7-digit or 10-digit, as required. To avoid modifying the existing equipment, separate groups of ticketers were added for PPCS but they are standard Type A SATT ticketers, modified only slightly to connect with associated auxiliary equipment that provides the controls for PPCS.

As soon as the PPCS call reaches the ticketer, a signal is sent to the ticketer finder-allotter in the long-haul facilities of the Type 53 SATT. A ticketer finder connects a multi-frequency register resender to the ticketer, and the Director register-sender immediately spills the called number into the register resender and retires from the call.

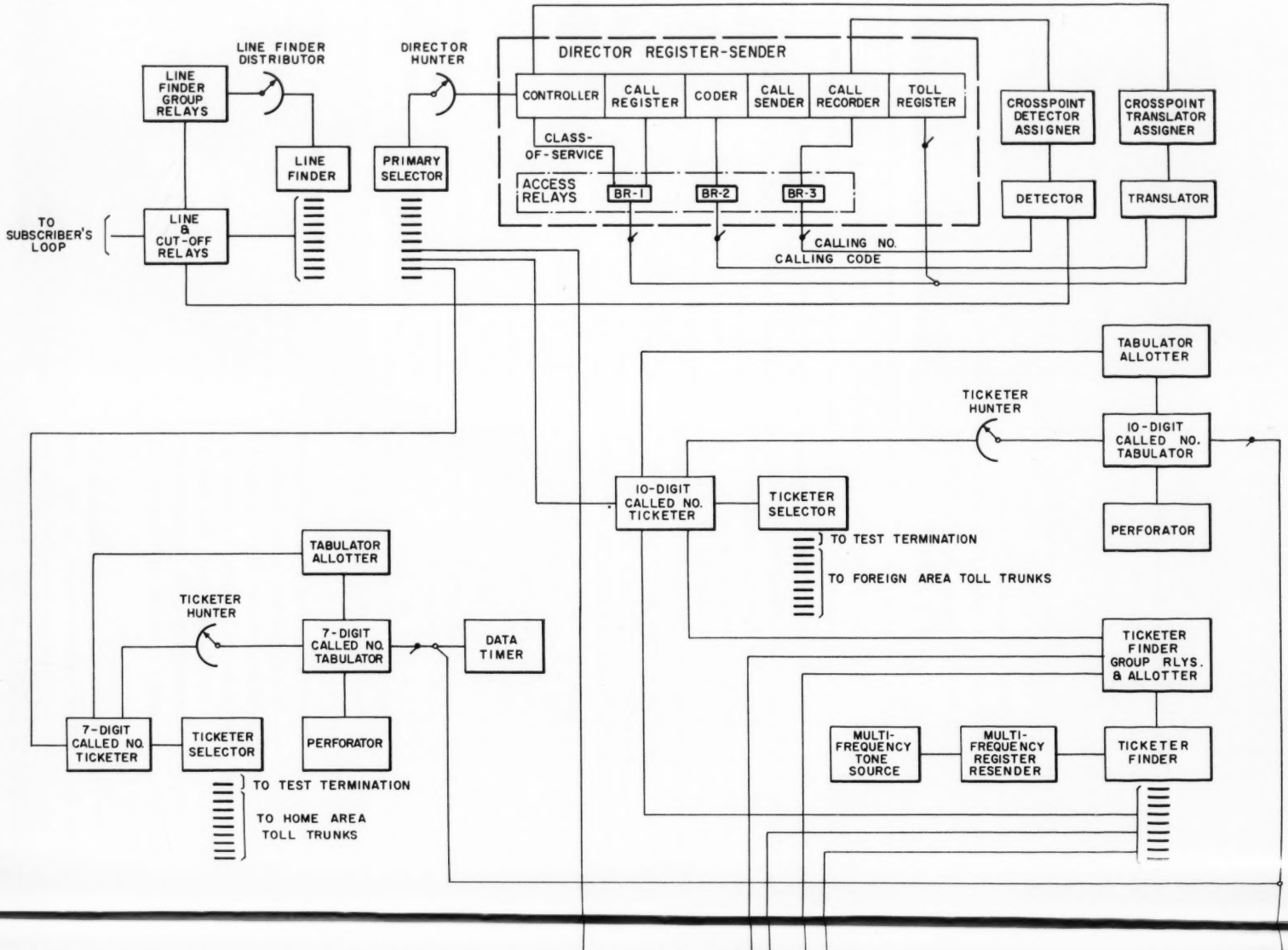
The PPCS ticketer has received ticketing data from the Director register-sender in the usual way, and has the called number stored in the MF register resender, ready for outpulsing. A signal to the link distributor causes a link to associate a position circuit with the PPCS ticketer. Outpulsing from the MF register resender then proceeds, and the position display storage receives from the PPCS ticketer three items of information totaling a maximum of twenty digits. These are the called number (10 digits) the calling number (7 digits), and the ticketer number (3 digits).

The PPCS position is a cordless desk, not greatly different from the sort that might be used as a CKO position. The most conspicuous addition is the display unit which enables the PPCS operator to read the twenty digits of stored information, ten digits at a time. A key causes either the called number, or the calling number in combination with the ticketer number to be displayed before her. Another key permits holding the display after the position has been disconnected from a call. A second, essential but less conspicuous, item on the PPCS position is a clock for use in writing special memorandum tickets.

PPCS Operator Procedure

When a ticketer has been associated with the PPCS position, the operator receives a tone signal to challenge the calling party with some phrase such as "May I help you?" After learning

*The Type 59 SATT System. F. L. Kahn. General Telephone Technical Journal, Vol. 6, No. 4, April, 1959, pp. 116-128.


LINE FINDER DISTRIBUTOR
DIRECTOR HUNTER
DIRECTOR REGISTER-SENDER
LINE FINDER GROUP RELAYS
CONTROLLER
CALL REGISTER
CODER
CALL SENDER
CALL RECORDER
TOLL REGISTER
CROSSPOINT DETECTOR ASSIGNER
CROSSPOINT TRANSLATOR ASSIGNER
CLASS-OF-SERVICE
LINE FINDER
PRIMARY SELECTOR
ACCESS RELAYS
BR-1
BR-2
BR-3
DETECTOR
TRANSLATOR
TO SUBSCRIBER'S LOOP
LINE & CUT-OFF RELAYS
CALLING NO.
CALLING CODE
TABULATOR ALLOTTER
TICKETER HUNTER
10-DIGIT CALLED NO. TABULATOR
10-DIGIT CALLED NO. TICKETER
TICKETER SELECTOR
PERFORATOR
TO TEST TERMINATION
TO FOREIGN AREA TOLL TRUNKS
TABULATOR ALLOTTER
TICKETER HUNTER
7-DIGIT CALLED NO. TABULATOR
DATA TIMER
TICKETER FINDER GROUP RLYS. & ALLOTTER
7-DIGIT CALLED NO. TICKETER
TICKETER SELECTOR
PERFORATOR
MULTI-FREQUENCY TONE SOURCE
MULTI-FREQUENCY REGISTER RESENDER
TICKETER FINDER
TO TEST TERMINATION
TO HOME AREA TOLL TRUNKS

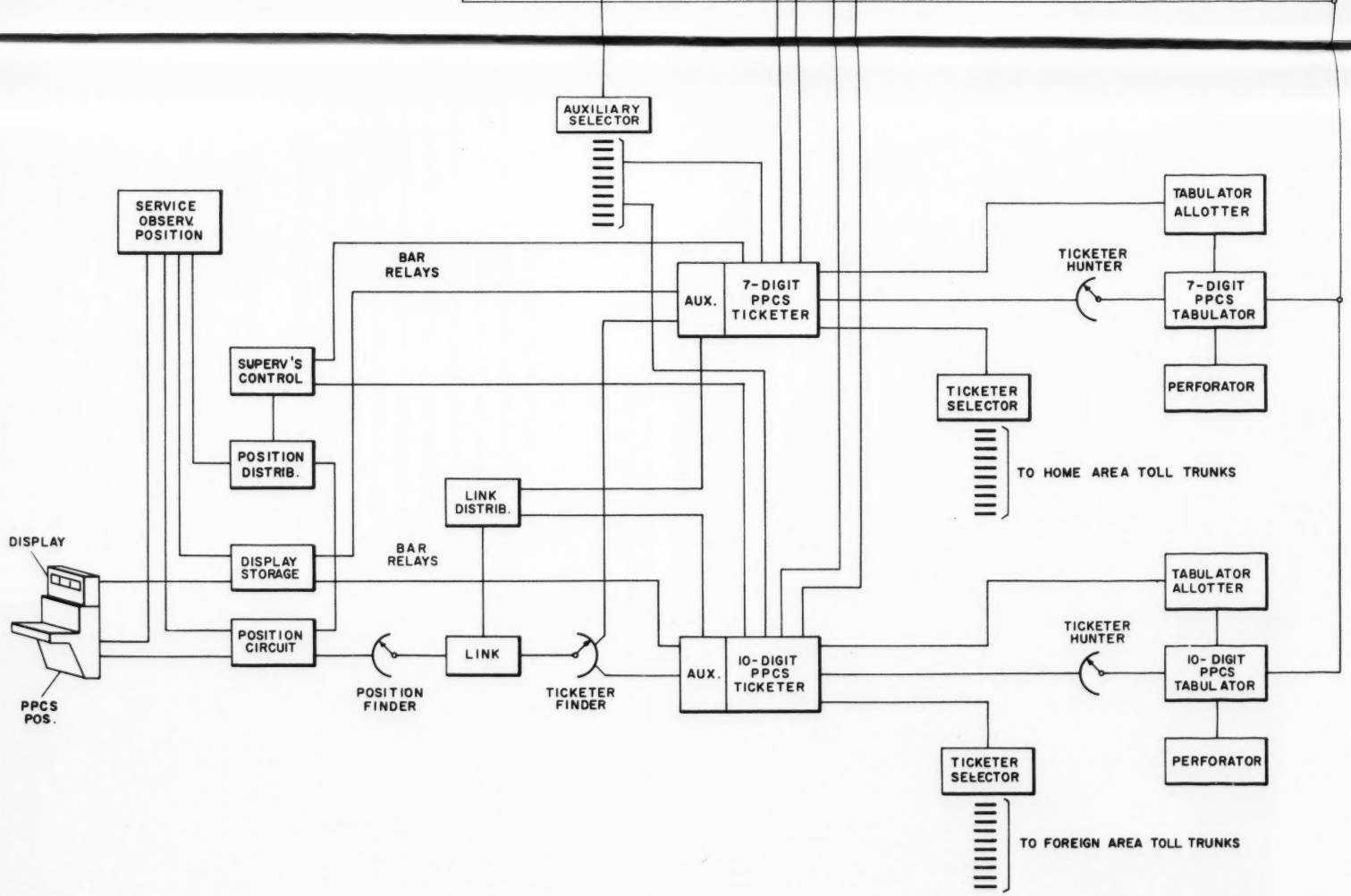


Figure 3. Block diagram showing how PPCS was added to the Type 53 SATT system at Pomona.

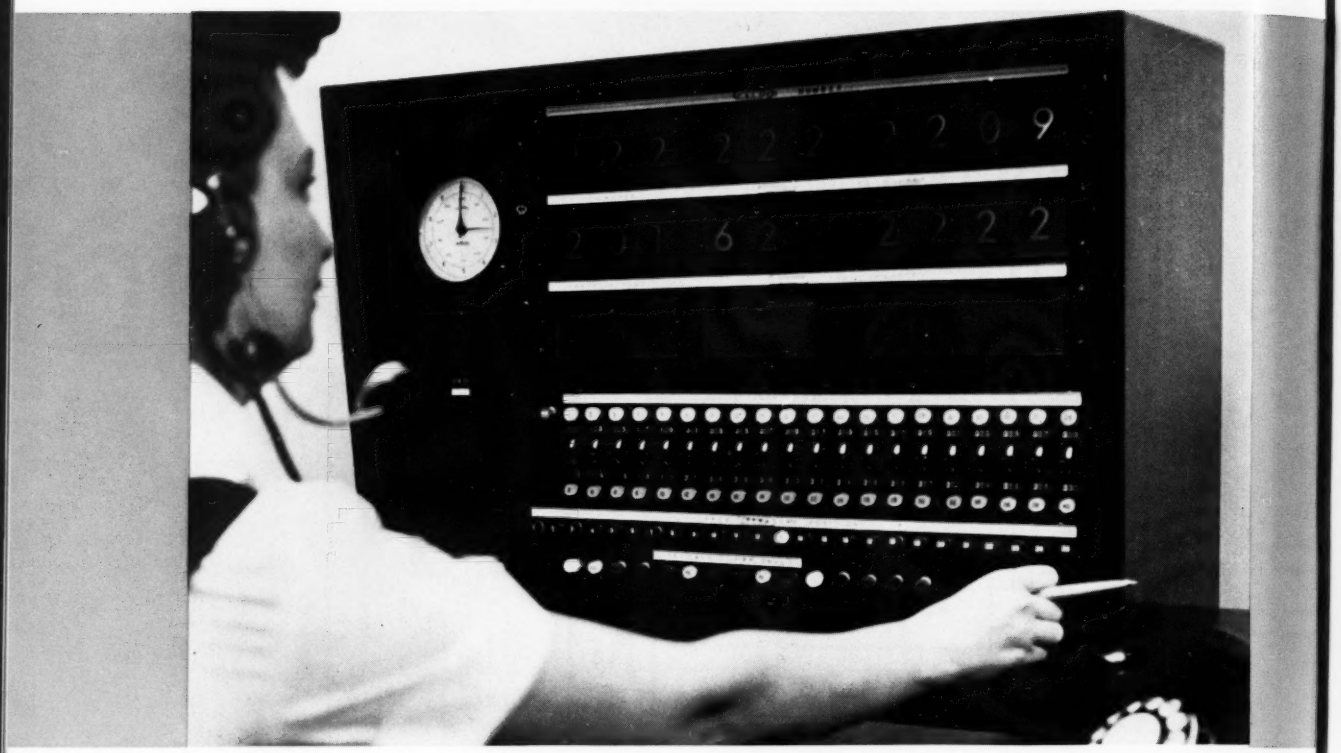


Figure 4. Service observation equipment includes panel for display of calling number, called number, ticketer number.

the calling party's wishes, the operator depresses one of six "class" keys to indicate whether the call is station-to-station or person-to-person, and whether it is paid, collect, or "bill per special memo ticket" (e.g., credit card or bill-to-third-number calls). If it is a special-instruction (memo ticket) call, the operator writes a ticket (in the Pomona installation, it is a mark-sense ticket), recording the "bill to" number, the date, clock time, and such other information as her instructions may specify (she obtains the called number, calling number, and ticketer number, of course, from the position display storage). Assuming that the call turns out to be billable, this ticket is later completed in the Accounting Department, by using information on the punch-card that was prepared from the entry on the SATT tape. (As usual with SATT equipment, no entry is made on the tape if the call is not completed.)

On paid or collect calls, the PPCS operator does not write a ticket. On collect calls she must, of course, secure acceptance of charges at the called station. If the charges are not accepted, but the calling party is then willing to pay for the call, the operator changes the class of the call, by depressing the appropriate "class" key. Called-party supervision is provided for the operator, but on a station-to-station call she need not wait for an answer unless the call is collect. On a person-to-person call, she must wait until the called person is on the line, or until she receives a report.

When the requirements applicable to the particular class of call have been met, the operator starts the timing but is still able to monitor the connection. If all goes well, she releases her position from the connection and is ready for another call. Should there be some difficulty before she has released, the operator is able to cancel the timing. Depending upon circumstances, she may re-start the timing if the difficulty is cleared up, or she may release the toll

line forward but remain in communication with the calling party.

If the call cannot be completed, the calling party preferably makes a subsequent attempt. The PPCS operator can, however, pass the call details to a toll position over a tie trunk, for completion on a delay basis. She may also do this when there is trouble, at the same time writing a trouble ticket for investigation by the maintenance staff.

Pomona has full automatic number identification (ANI). The PPCS position circuit therefore has no provision for the PPCS operator to do number checking (CKO) on either PPCS or station paid SATT calls.

The keyset on the PPCS position is not used at Pomona now. It will be needed if at a later date the operator is given a means of changing the called number for a second attempt, when she receives a report that the called person can be reached at another number.

There is no way for the calling or the called party to recall the PPCS operator after the position has been disconnected. Therefore it is desirable that the operator continue monitoring after timing has been started, until she is sure everything is all right.

The link distributor and the link with its associated finders are some of the circuits borrowed from Type 59 SATT. So also are the position distributor and supervisor's control circuits, whose functions have not been mentioned but are suggested by their names. Type 53 SATT circuits (tabulator allotter, tabulator, ticketer hunter, and perforator) are used to make the tape records of PPCS calls. These tapes must carry the class of the call, in addition to the usual tape entries.

Miscellaneous Services

Because of the trial aspect of the Pomona installation, service observation was essential; this required design of entirely new equipment (see Figure 4) for the service-observing position. This service-observing equipment is unique to the Pomona installation; SATT systems handling station-paid calls do not seem to need such equipment — probably because if operators are involved at all, it is only for the CKO function— a very simple matter of obtaining and keying the calling number.

A wall-mounted display panel (Figure 5) is also provided for the supervisors; its display includes call-waiting lamps.

As there is no Independent toll board at Pomona, it was not possible to modify an existing toll position for night service on PPCS. However, the General Telephone Company of California operates an information board in the Pomona main office, and a PPCS position was placed next to one of the information positions (see Figure 6) so one operator can work both positions for night service.

Multi-Frequency Pulsing

The use of the MF register resender for outpulsing all PPCS calls is deserving of some explanation. A combination of buffer storage and sender was needed, to avoid making extensive changes in a large number of Director register-senders. The MF register resender fills this need very nicely for calls which can be forwarded by multi-frequency pulsing; it was found possible to make special arrangements with the P.T. & T. Co. at Pomona for routing all PPCS calls so that

Figure 5. Wall-mounted display panel informs supervisors of service being rendered by PPCS operators.

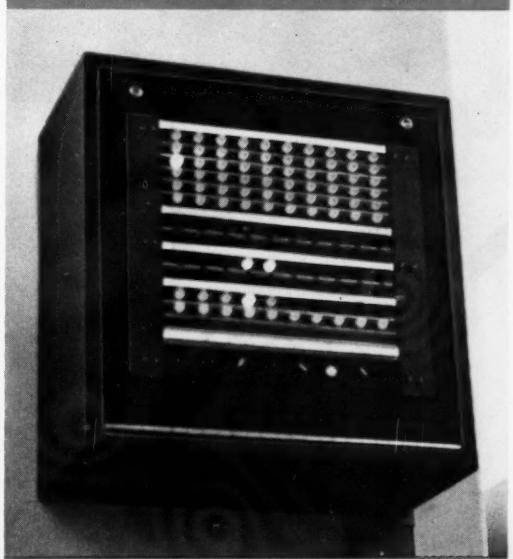


Figure 6. For night service, PPCS position is worked by information operator.

they could be handled in this way. This obviated the necessity of developing a circuit to store and resend dial pulsing.

Summary

In the latter part of May, after the PPCS service had been generally available for just over two months, Pomona was handling up to about 900 PPCS calls in a day. A maximum of five PPCS operators was required during the busy hour. The ultimate capacity of the ten regular PPCS positions should be rather more than double these figures, considering the expected increase in efficiency as the operator team size increases.

The PPCS equipment operating at Pomona differs in two important respects from the equipment needed for exchanges which use a SATT access code and which do not have Director register-senders. First, the Pomona system must work with a Type 53 SATT system rather than a Type 59. Second, it is designed for trial installation as a separate system working with existing equipment, rather than as a part of a fully integrated SATT system. Nevertheless, the volume of traffic handled on PPCS at Pomona is sufficient to constitute a very good field trial, and the results are being followed with much interest.

R. B. King attended Wheaton College, Wheaton, Illinois and continued his technical studies in evening classes after entering the employ of Automatic Electric Company in 1925. He started in shop work but was transferred to engineering in the same year. Much of his time has been spent in circuit and mechanical testing and adjustments. From 1946 until 1956 he was supervisor of the Test Bureau. He is now Supervisor of Toll Ticketing Development. He is a member of A.I.E.E.

A "HIGH DENSITY" CARRIER TELEPHONE SYSTEM

By Robert C. Herrick, Matthew L. Stephens, and William J. Tobin
Lenkurt Electric Co., Inc.

Heavy toll traffic is making it necessary for many telephone companies to provide large groups of toll-quality channels between areas of high traffic density. Carrier operation, particularly on radio, offers a most economical means of providing these channels, and Lenkurt engineers have developed a "high-density" carrier system specifically adapted for the purpose. This Type 46A Carrier Telephone System (see Figure 1) is a transistorized system for transmitting large or small groups of toll-quality carrier telephone and signalling channels over a single transmission medium. It is particularly suited for, but not restricted to, radio circuit application where up to 600 channels may eventually be required.

Transistorized circuits are assembled in functional equipment packages, and a 600-channel terminal, including spare equipment, can be mounted in as few as twelve standard equipment racks. Installations initially containing a limited number of channels can be easily expanded to full capacity. Dependability is obtained through the use of parallel or alternate circuits. The 46A is designed to coordinate with other carrier systems such as the Western Electric L Carrier System and the Lenkurt 45BX Carrier System, and to comply with CCITT recommendations.

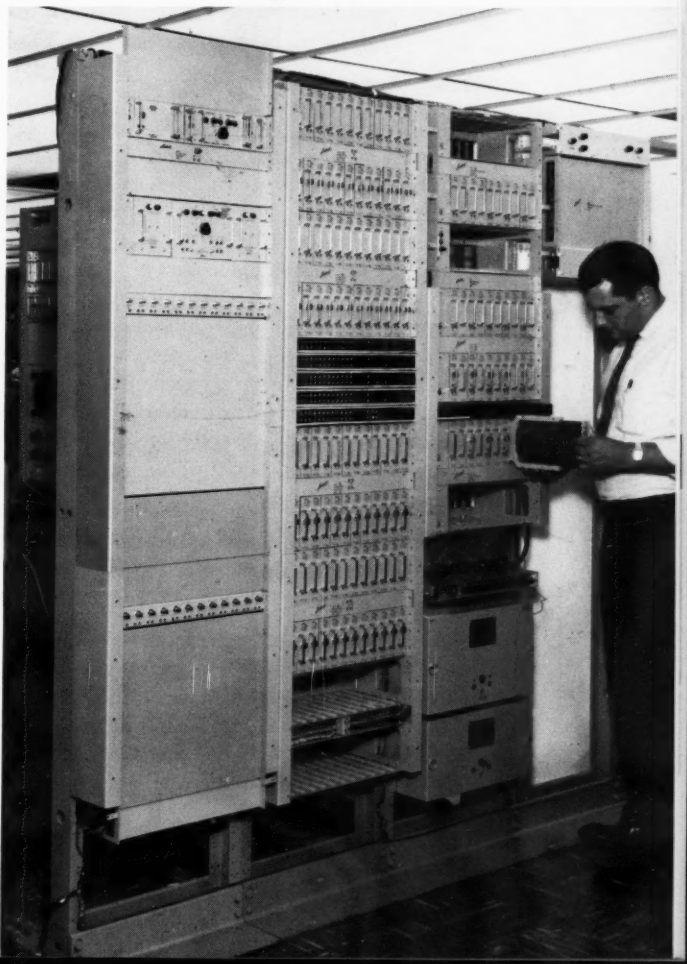


Figure 1. A typical assembly of Type 46A equipment. Mr. Tobin holding one of the plug-in card units, removed from the rack.

Modulation Plan

To combine groups of channels into a single baseband, and to separate the baseband into individual channels, the 46A system uses the three-step modulation plan shown in Figure 2. In Step 1, voice-frequency information associated with each channel modulates one of 12 carriers used in the system; this process results in a "bank" of 12 single-sideband, suppressed-carrier outputs, which are then combined into a band of frequencies (referred to as a "group") that extends from 60 to 108 kc. In step 2, each group modulates one of five group carriers, producing

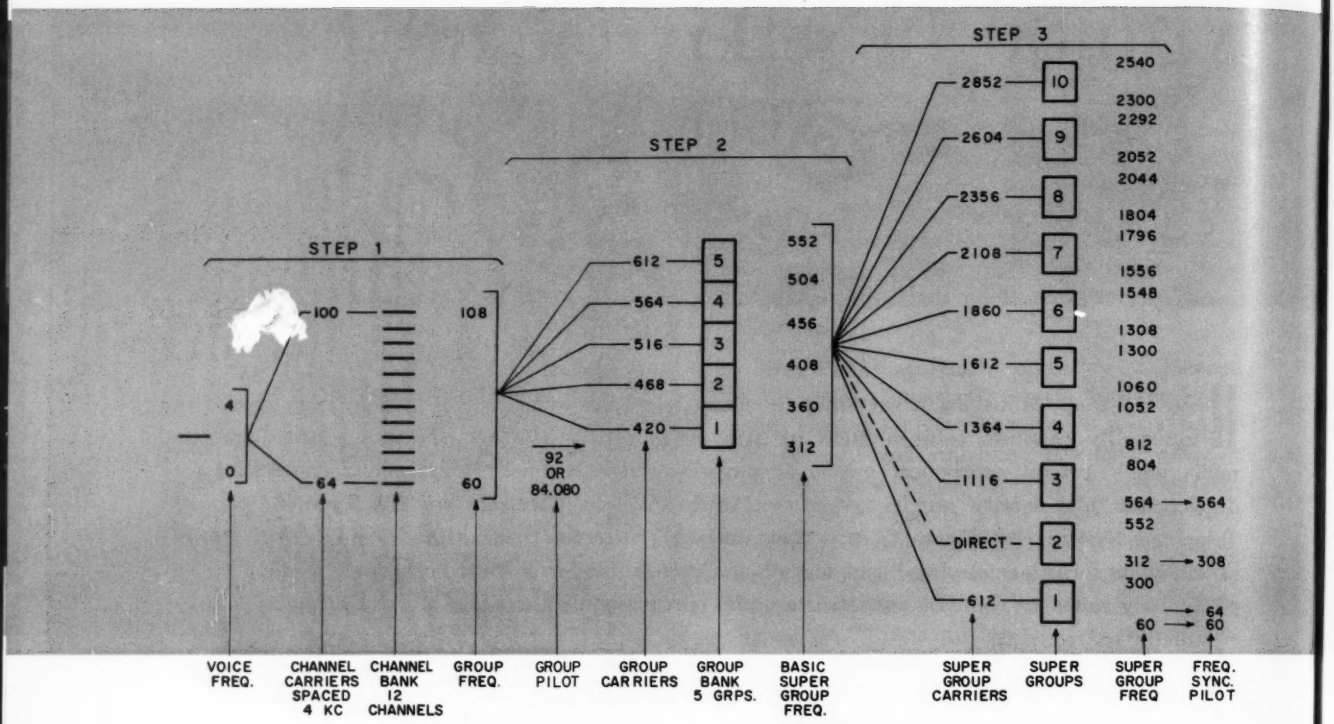


Figure 2. The three-step modulation plan used in the 46A system.

a single-sideband, suppressed-carrier output, and the "bank" of five group outputs is combined into a band of frequencies (referred to as a "basic supergroup") that extends from 312 to 552 kc, and contains the information originally contained in 60 individual channels. In Step 3, a basic supergroup is used to modulate one of nine supergroup carriers; the nine outputs (each called a "supergroup") are combined with a basic supergroup to form a baseband of line or basegroup frequencies extending from 60 to 2540 kc, which are applied directly or through line equipment to the associated radio transmission equipment.

Separation of the baseband into individual channels is accomplished by essentially the reverse of this process.

A group pilot frequency of either 92 kc or 84.08 kc is provided, and a line pilot for frequency reference may be chosen from frequencies of 60, 64, 308, and 564 kc. Signaling frequency is either 2600 cps for in-band signaling or 3825 cps for out-of-band signaling.

System Description

As shown in Figure 1, Type 46A equipment consists of individual equipment units which plug into pre-wired shelves, mounted on standard 19-inch equipment racks. The equipment projects approximately five inches from the rack face, with an overall depth of ten inches, and is cabled and serviced from the front so that back-to-back installation of racks is permissible. (On large installations, duct-type bays are recommended to accommodate the necessary cabling.)

Mechanical construction of the 46A equipment is quite similar to the construction of Lenkurt's 81A Exchange-Trunk Carrier System*. Lenkurt's "stitched wiring" process, on computer-style, plug-in cards, is utilized, and the faceplate of each unit provides test points and adjustments. Basic shelf and connector arrangements for the 46A are the same as on the 81A, but additional terminal blocks and cabling areas are provided for the required external connections.

*The Type 81A Exchange-trunk Carrier System, M. R. Dunning, Automatic Electric Technical Journal, April, 1961.

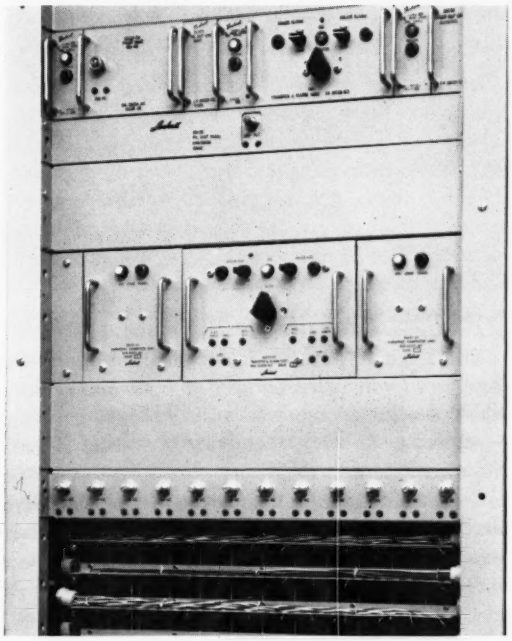


Figure 3. Carrier- and pilot-generation equipment of the typical 46A assembly shown in Figure 1.

The system may be divided functionally into four parts as follows: (1) transmission equipment, (2) signaling equipment, (3) carrier and pilot-generation equipment, and (4) alarm and transfer equipment.

Transmission Equipment

The transmission equipment consists of the channel bank, the group bank, the supergroup, and the line equipment; in this equipment, up to 600 channels are processed through the modulation and demodulation steps described previously. Each channel bank normally holds twelve "transmit" and twelve "receive" channels, but for unidirectional operation it may be equipped with all "transmit" or all "receive" units.

A group bank usually holds five "transmit" and five "receive" groups, which can handle 60 channels of two-way transmission; however, the group bank also can be equipped with either all "transmit" or all "receive" units. The supergroup shelf holds three modem units, each of which accommodates 60 channels of information.

For a full 600-channel system, 50 channel banks, ten group banks, and three supergroup shelves with nine modems are required. For smaller systems, only the equipment required for the number of channels to be used need be installed. Line amplifiers and cable equalizers are common to all channels, and the number required is determined by the particular system application.

Signaling Equipment

Plug-in signaling units are available either for in-band or for out-of-band signaling. In-band signaling units are mounted six to a shelf; two of these shelves are required to provide one channel bank with signaling. Out-of-band signaling units mount twelve to a shelf. Both in-band and out-of-band signaling applications use an external signal-frequency supply that can provide a signal tone to as many as 144 signaling units.

Carrier- and Pilot-Generation Equipment

Carrier and pilot frequencies (except for the 84.08 kc pilot) are developed from basic frequencies of 4, 12, and 124 kc that are produced in a master frequency generator, from a pair of highly stable, 128-kc master oscillators. The three basic frequencies are used as follows:

(1) To provide channel carrier frequencies, the 4-kc output is amplified in a transistor power stage and this high-level 4-kc signal is applied to a saturable-core harmonic generator which produces odd harmonics of 4 kc. Even harmonics are then obtained through full-wave rectification of the odd harmonics. Harmonics which fall between 64 and 108 kc are selected by means of narrow filters. There is more than sufficient power available from each filter (+14 dbm) to drive 12 channel modems without further amplification. All of the carrier power for 12 channel banks (12 frequencies, 12 modems per frequency, 144 channels, transmit and receive) is obtained from the 4-kc power amplifier. Total power input to the amplifier is about 4.1 watts. For systems larger than 144 channels (120 channels plus spares), carrier-frequency booster amplifiers are provided.

(2) The 12-kc output is used in a similar fashion to derive frequencies of 420, 468, 516, 564, and 612 kc, which are used as group carrier frequencies (the 612-kc frequency is also used as the supergroup 1 carrier frequency).

(3) The 124-kc basic frequency is used to drive a harmonic generator circuit on each of the three supergroup shelves. The particular harmonic required for each supergroup carrier (supergroups 3 through 10) is selected by a filter in the supergroup modem unit requiring that frequency.

Pilot frequencies are obtained basically from the group and channel carrier supplies. Signals from these supplies are amplified, regulated, and multiplied as required to obtain the desired pilot frequencies. In the case of the 84.08-kc group pilot, a separate oscillator is provided.

Alarm and Transfer Equipment

In a 600-channel terminal, it is very important that functions common to many channels, such as the 4-kc harmonic generator, be extremely reliable. Transistors are generally regarded as many times more reliable than vacuum tubes; system reliability has been further assured by providing duplicate or parallel circuits wherever more than 12 channels would be affected by failure of active circuitry. For example, the 128-kc master oscillator is provided in parallel; under normal conditions both oscillators are in phase and share the load equally, but in the event of a failure in one unit, the other takes over without interrupting service. Duplicate line amplifiers also are provided to handle the full system load of 600 channels. In case of a failure of one amplifier, the other unit is switched into service with a minimum of interruption (provision has also been made for maintenance switchover with no interruption).

Transfer and alarm equipment monitors operation of the alternate paths, and actuates transfers as necessary. Monitor alarms are provided for all critical parts of the equipment. "Minor" and "major" alarms are provided: any failure that does not disable more than 12 channels will operate a minor alarm, while any failure that disables more than 12 channels will activate a major alarm.

Since group pilots traverse the system from group transmit to group receive on a twelve-channel basis, group pilot alarms function as a system alarm. Upon loss of a group pilot, an alarm circuit will operate office alarms; auxiliary alarm equipment can also be activated to disconnect drop circuits and give busy indication through the signaling equipment.

In addition to the above-described functional equipment, there are many accessory items necessary to the practical application of any carrier system. Such items as power supplies, fuse panels, jack facilities, etc., fall into this category. All are available in suitable sizes and configurations for use with 46A equipment.

Performance

The Type 46A system is designed for operation from −48 volt office battery or equivalent. Normal operation is achieved with voltages between −46 and −52 vdc; emergency operation is possible with voltages as low as −42 volts or as high as −54 volts. Due to liberal use of transistorized circuits, the channel bank equipment requires less than one watt per channel, and the group bank equipment requires less than 15 watts per group of 60 channels. Power consumption for a 600-channel terminal with in-band signaling is 1500 watts.

All channels of the 46A equipment have uniform characteristics. Overall frequency response of each channel is within +0.5 db and −0.75 db between 450 and 2950 cps. The −3 db points are nominally 250 and 3400 cps. Envelope delay of the average channel is less than 500 microseconds between 700 and 2950 cps, and all channels are within approximately 25 microseconds of the average delay characteristics.

Speech peak limiting is accomplished in each channel by means of diode limiters which precede the channel modulator. A gain reduction of approximately 1 db results from an output power 8 db above test tone. The channel modulator sets the limit at about 18 db above test tone, and the receive amplifier at about +17 dbm.

Non-intelligible crosstalk coupling loss in the channel bank exceeds 63 db, F1A weighted. Sidetone coupling loss exceeds 50 db.

For normal −16/+7 dbm lineup, all channel distortion products are more than 40 db below test tone. Channel and group carrier leaks to the line do not exceed −25 dbm0 per modulator.

The channel bank makes a negligible contribution to idle noise; the group bank contributes about 10 dba, FIA weighted, at a point of zero

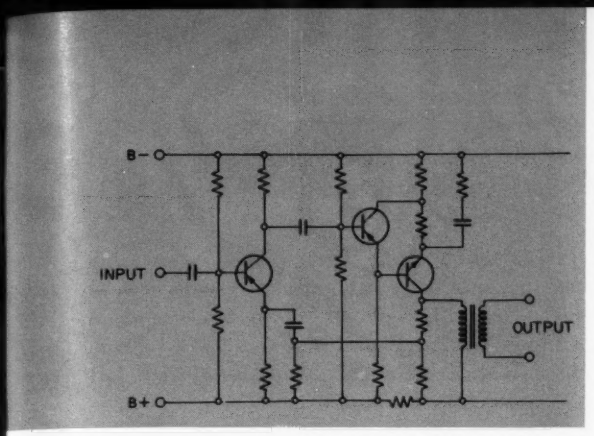


Figure 4. Two-stage, three-transistor amplifier uses feedback compound in second stage, to provide maximum power, gain, and bandwidth.

relative level. Idle noise does not exceed 15 dba for the full 600-channel system (exclusive of transmission medium). Busy-hour noise due to intermodulation does not exceed 23 dba, F1A weighted, for two terminals (exclusive of the transmission medium). The busy-hour load is represented by a power of +17 dbm0 for the 600-channel system, and includes an allowance for voice traffic on 75% of the channels, and SAGE or telegraph data on the remainder. (For comparison, the CCITT recommended loading is represented by a power of +13 dbm0.)

Channel bank and group bank level stabilities are each better than ±0.25 db for supply voltage fluctuations of 10%, and are approximately ±0.5 db for ambient temperatures between 0°C and 50°C. All terminal frequencies are harmonically related to a basic 128-kc frequency, which is crystal-controlled for stability; deviation is approximately 2 parts in 10 million per 3 months. Drop-to-drop frequency error will therefore not exceed 1 cps for the worst channel, during the 3-month period.

Design Highlights

The Type 46A system incorporates many unique design features. The 60 to 108-kc basegroup is achieved through direct modulation and the use of L-C channel filters. (In the past, direct modulation has required crystal elements in the filters because of the Q requirements, but Q's exceeding 600 are now obtainable in ferrite-core inductors, and the 46A channel filters make use of these inductors.) Very close control of inductor and capacitor temperatures and retrace characteristics is required in order to hold satisfactory filter response.

Older carrier systems have used copper-oxide-type ring modulators, or, more recently, germanium diodes. The 46A system makes use of germanium transistor modulators, both in the traditional ring or lattice configuration for group modulation, and in a less conventional shunt switch arrangement for channel modulation. When compared to diode modulators, transistor modulators exhibit lower losses and lower distortion, for the same carrier power (or, for the same distortion, less carrier power or a higher level is possible). For example, the 46A channel modulator requires only one transistor, provides an insertion loss of 5 db, requires a carrier power of −3 dbm, and makes a contribution to channel distortion of typically −50 dbm0. Performance of the four-transistor group modulator is equally impressive.

Transistor Amplifiers

Considerable use is made in the 46A system of a two-stage, three-transistor amplifier circuit. The first stage is a conventional grounded-emitter amplifier, but the second stage is a two-transistor arrangement known as a "feedback compound" (Figure 4 shows a typical circuit diagram in which the compound is used as a grounded emitter). Compounded transistors in general combine the power-handling capability of the output transistor with the gain and bandwidth characteristics of the input transistor. The feedback compound offers better frequency response and less distortion than the more familiar Darlington compound. The same amplifier configuration is used at voice frequency for the channel receive amplifier, and in both group transmit and group receive amplifiers. In every case, stability and distortion ratios are more than adequate.

Application

Basically we think of a carrier system as a facility to carry information between two points. With a large-capacity system, however, it is improbable that the full capacity would be used between the same points; almost invariably some of the circuits are terminated at intermediate points, connected to branch circuits, extended over other facilities to a different type of terminal, or otherwise treated. Therefore, it was recognized, early in the development of the 46A system, that the equipment had to fulfill a limitless variety of applications in order to fit the network

concept, wherein it is just part of a national or intercontinental communications network.

A number of features of the 46A equipment are important to this concept. The modulation plan and channel performance conform to CCITT recommendations. They also coordinate with the "L" system in supergroups 2 through 8. The 46A, therefore, can connect end-to-end with "L" and CCITT-conforming equipment, and can operate side-by-side on the same transmission facility with such carrier systems. Pilots are provided in coordinating frequencies and levels, permitting integration of the alarm and monitor functions governed by these pilots.

Out-of-band signaling at 3825 cps conforms to CCITT recommendations, for coordination with other such systems. The 2600 cps in-band signaling is designed to operate end-to-end with Western Electric Type E signaling. The 46A channel bank and in-band signaling equipment can also be substituted for equivalent Western Electric equipment and can use Western Electric channel carrier and signaling supplies.

Flexibility of system arrangement within the 46A, and with other radio carrier systems such as the Lenkurt 45BX system, is provided by a series of filters and associated line equipment. These items permit bridging, branching, reinsertion, and interconnection of channels on a point-to-point or party-line basis at a variety of intermediate terminals.

Summary

The Lenkurt Type 46A Carrier Telephone System has been designed to fill the widespread need for an economical and compact method of providing long-distance communication channels in quantity. It uses modern electronic techniques to meet the widely varied requirements encountered in such applications.

Robert C. Herrick, (left) Project Leader for Application Engineering of the Type 46A system, was responsible for its coordination with existing telephone plant facilities.

Matthew L. Stephens, (right) Project Leader for Development Engineering, is a member of AIEE and has been closely associated with the design of ultramodern communication equipment which employs transistors to the complete exclusion of tubes.

William J. Tobin (center), with a background of ten years in technical writing, has responsibility for all instruction material and specifications on ordering, installation, operation, and maintenance related to the 46A system.

APPLYING THE AT-6 NEGATIVE-IMPEDANCE REPEATER

By M. J. Leach
Automatic Electric Company

The AT-6 Negative-Impedance Repeater, recently introduced,* is a fully transistorized, "series-shunt" unit in one package (see Figure 1). As compared to earlier repeaters, it contains a number of significant improvements, such as greater reliability, only half the size, stable gain (and more of it), and simpler line-up procedures. The AT-6 uses a purely resistive network for gain control, and as part of its line-up procedure LBO (line build-out) units are adjusted to the lines to make them appear substantially similar to a 900-ohm resistor in series with a 2 mf capacitor. This difference in fundamental concept from previous negative-impedance repeaters requires that different techniques be used in applying it to the telephone plant. These techniques are outlined in this article.

Basically, the AT-6 Repeater consists (see Figure 2) of a gain unit, shunt and series sections, and two LBO units—one on each side of the gain unit. If the repeater is used at the terminals of a circuit, a dummy LBO (a pair of "straps") is used on the office side of the unit; the office is assumed to have a 900-ohm impedance and thus does not require matching to the gain unit.

The AT-6 Repeater is intended primarily for application to voice-frequency-loaded cable pairs having uniform impedance characteristics. It can also be applied to non-loaded cable pairs and at the junctions of loaded and non-loaded facilities, but these applications are not discussed in this article. It is expected to find wide application on toll terminal trunks, local trunks, tandem trunks, and foreign exchange and special service lines. It should also find ready application to the longer PBX trunks and tie lines, as well as to long "off-premises" PBX station lines.

Due to return loss considerations, negative-impedance repeaters (or any two wire voice frequency repeater) are not permissible on intertoll circuits, nor at the toll-switching end of toll terminal circuits. They should be confined to the "end-office" terminal or to intermediate locations falling within the middle one-third of the line facility.

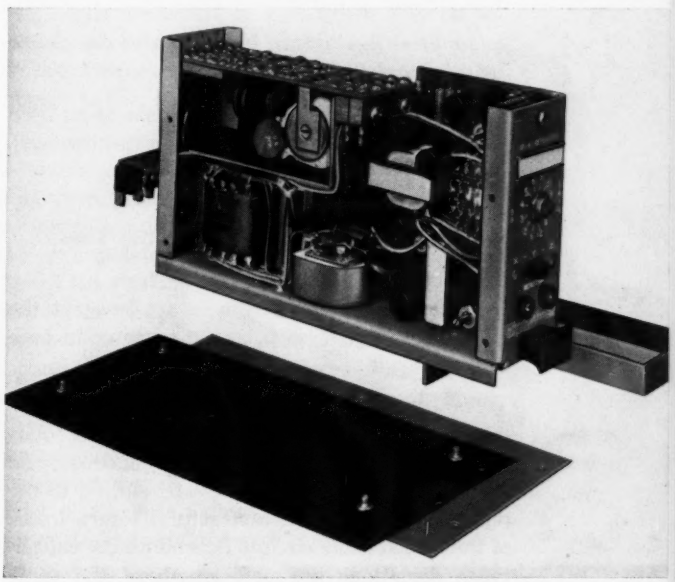


Figure 1. The Type AT-6 Repeater (shown with covers removed) is a compact, transistorized unit, with provisions for setting the LBO units by means of screws in the top panel, and for easily adjusting the resistance network from the front.

*New Negative-Impedance Repeater Permits Accurate Impedance Matching, R. P. Dimmer, Automatic Electric Technical Journal, April, 1960.

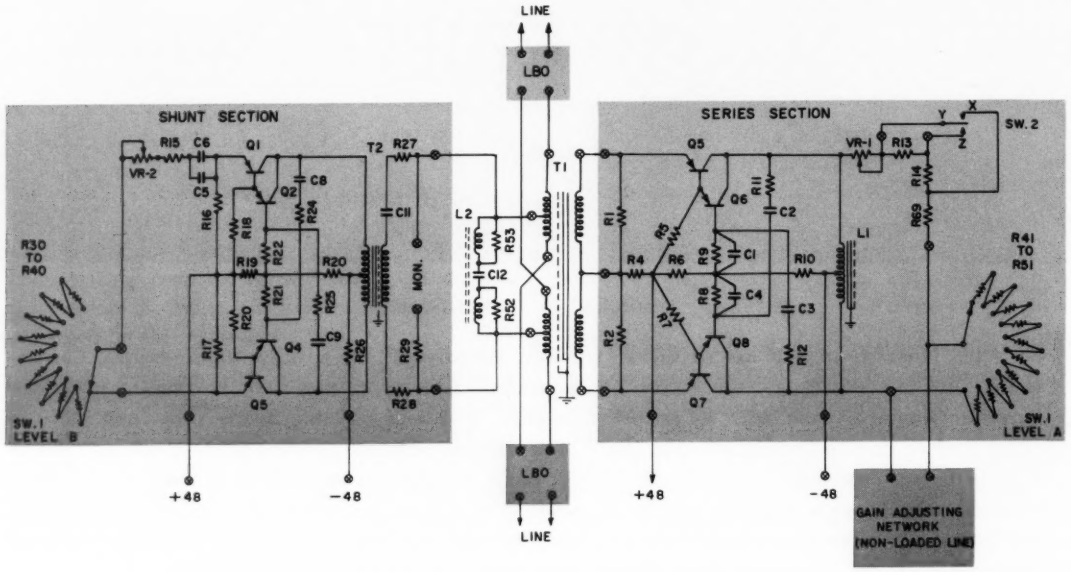


Figure 2. This circuit drawing of the AT-6 Repeater shows the series and the shunt sections of the gain unit and the LBO's.

Applying the AT-6 Repeater involves at least three distinct and relatively unrelated operations:

(1) Find the "return loss' between the circuit facilities and the repeater gain unit.

(2) Determine the amount of gain to be used as well as the effects on signaling ranges involved.

(3) "Line-up" the repeater.

Finding the "Return Loss" of the Line

The allowable gain obtainable from an AT-6 Repeater depends upon the return loss (at the critical frequency) seen by the repeater in both directions.

The return losses are a measure of the reflections from the ends of the facility, from intermediate equipment (such as repeating coils), and from structural irregularities—all referred to the repeater gain unit. The structural return losses of the loaded cable circuits depend on the capacitance deviations per unit length of the cable itself, the inductance variations in the loading coils, and (predominantly) the regularity of the load coil spacing.

There are several ways of determining the return losses to be used in calculating the potential repeater gain. Ideally, of course, the losses should be measured. Alternatively, the probable return losses can be calculated from the known load-coil spacings, obtained from actual plans or field measurements. A third method involves making the assumption that at least the minimum required structural return losses (as shown in Figure 3) will be obtained in all cases if—

(1) The average spacing of the load coils does not deviate from the nominal spacing by more than $\pm$ 2%, *and*

(2) Each loading section length is within $\pm 2\%$ of the average of all sections in a given cable, *and*

(3) The average deviation (disregarding signs) from the average spacing does not exceed $\frac{1}{2}$ of 1%.

In any event, the terminal, intermediate, and structural return losses are referred to the repeater gain unit by adding twice the attenuation intervening between each irregularity and the

Facility	Structural Return Loss in db
19H88	16
22H88	19
24H88	23
19D88	16
22D88	19
24D88	23
19B88	16
22B88	19
24B88	23

Figure 3. Minimum structural return losses based on loading meeting the requirements outlined in this text.

repeater. These several referred return losses are combined, on a power basis, to arrive at the overall value of return loss which is to be used in determining the repeater gain.

It must be noted that the LBO units are in the transmission path between the repeater gain unit and the line facilities; accordingly, they must be taken into consideration in referring the return losses to the repeater gain unit. It is not possible to assign a constant value to the losses caused by the LBO's, since their attenuation will vary with the amount of building-out they have been adjusted for.

The LBO units are basically "impedance equalizers" and are also referred to as impedance compensators. Their function is to modify the normal impedance of a loaded cable pair to closely approximate that of a 2 mf capacitor in series with 900 ohms (this is also the impedance of the repeater gain unit which it is required to match). The LBO's consist essentially of adjustable resistors and capacitors, and a fixed, high-frequency resonant circuit. The losses introduced in the LBO's are those of an artificial line which is equivalent to the length of loaded cable that would be needed to make the *actual* loading end section equal to approximately .8 end section.

The R and C component values to be used are dependent on the length and gauge of the cable "end section" to be built-out, and constitute an "artificial line" with which up to approximately one mile of typical cable may be simulated. The low-frequency correction is independent of the length of the cable end-section but depends on the gauge of the cable pairs involved. Low-frequency correction is accomplished essentially by varying the gain of the shunt gain element of the repeater, at the lower frequencies.

As the high-frequency corrector is fixed for a given type of loading, it follows that a different LBO unit is needed for each type. LBO's are available, or under development, for the H-88, D-88, B-88, and D-66 loading patterns, which are most used.

Determining the Gain of the Repeater

The AT-6 Repeater is capable of providing up to 12.5 db of gain under ideal conditions; the actual gain which can be applied to the line in a given situation will, however, always be less. The several factors which limit the usable gain include:

(1) The return losses facing the repeater,

(2) The attenuation of the facility before adding the repeater,

(3) The net loss or effective attenuation desired after adding the repeater, and

(4) The noise and crosstalk considerations.

The maximum values of gain which may be obtained (on loaded cable) with various values of critical frequency return loss are as shown in Figure 4.

It must also be remembered that the total available gain will be reduced by the unavoidable attenuation inherent in the LBO units. The permissible gain for an intermediate repeater is the extrapolated value between the diagonal "gain" lines at the intersection of the line representing the return loss (at the critical frequency) for section "A" with the corresponding line for section "B". Similarly, the permissible gain for a terminal repeater is determined by assuming a "zero" return loss for the line section "A" (the central office). By extrapolation, it can be seen that on this basis a terminal return loss of the order of 22 db is required before a terminal repeater may be operated with gains as high as 9 db.

The gain values shown in Figure 4 are purposely conservative, in order that an adequate margin of safety will be maintained against the repeater singing under the worst permissible con-

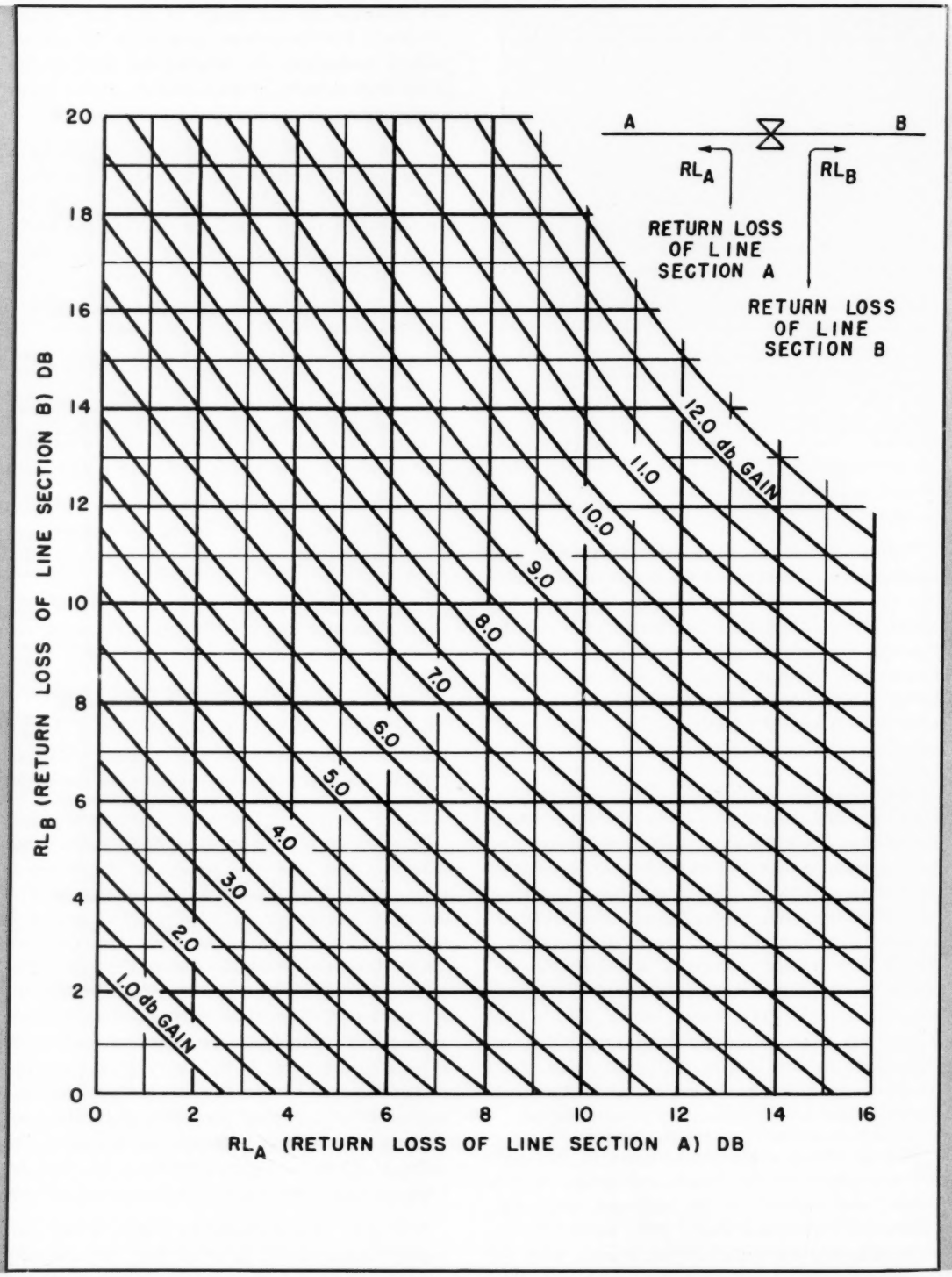


Figure 4. Maximum gain obtainable with the AT-6 Repeater versus line return losses.

ditions; conversely, somewhat higher gains are obtainable under the most favorable conditions. Approximately 4 db higher gains may be obtainable from intermediate repeaters (within the gain range of the repeater) on underground cable circuits, which are not subject to widely fluctuating temperatures and for which it is possible to obtain LBO unit adjustments producing return losses of the order of 25 db in both directions.

As a practical matter, the gain may not in any event be higher than that which will offset approximately 80% of the line attenuation (it is not possible to offset 100% of the attenuation of a line facility, even if it is as low as 6 db). With the total available gain of 12.5 db it may be possible with an intermediate repeater, under favorable conditions, to reduce a 15 db line facility to a net loss of about 3.0 db.

Limitations on Maximum Gain

It was pointed out above that at terminal repeaters as much as 9 db gain may be secured under some conditions; this gain would, however, be reduced by the attenuation introduced by the LBO unit, thus leaving a net gain of perhaps 8 to 8.5 db. Since this amount of gain applied on loaded cable facilities by a terminal repeater may result in objectionable crosstalk, it may be necessary in some cases to further limit the gain — for example, to about 7.0 db. Terminal repeaters should not be operated at gains higher than 7 db unless it is definitely known that better than average crosstalk conditions prevail.

As the configuration of the AT-6 Repeater is completely balanced, it will not tend to cause noise on a circuit which is subject to longitudinal induction or earth potentials; however, any noise already present will be amplified. One of the reasons why the gain at frequencies below 300 cycles per second has been kept at a minimum is because noise tends to be more severe in these lower frequencies.

It is obvious that insertion of the coupling transformer windings and of the LBO units, with their building-out elements, into the line facilities will affect d-c signaling. Different methods of signal path operation are affected in differing degrees, not only by the increase in d-c resistance but also by the pulse-distorting effects of inductance and capacitance. It is therefore necessary to take these factors into account in any practical application of the repeaters. Generally, however, the distortion caused by the repeaters will be within the operating margins of the various central-office circuits involved. The range-reducing effects are therefore largely confined to the effective increase in resistance introduced into the line by the gain-unit transformer and the LBO units themselves.

Any signaling method using tones, such as SF or MF pulsing, will not only be passed unimpaired but will actually be amplified by an amount equal to the gain of the repeater at the frequencies involved.

The usual ringing frequencies (of the order of 16 to 66 cps) will pass through the repeater but will suffer substantial attenuation, largely caused by the coupling transformer. The effect on ringing due to a single terminal or intermediate repeater may be equivalent to increasing the line resistance by as much as 300 ohms, while for two terminal repeaters on the same pair it may be equivalent to almost double this amount.

"Lining Up" the AT-6 Repeater on Loaded Cable Pairs

If the cable loading end section is known, we should theoretically be able to prescribe an adjustment for the LBO unit which will achieve an optimum return loss between the cable and the gain unit. For the more common types of loaded cable facilities, such "prescriptions" are, in fact, supplied in the form of tables. However, the optimum adjustment usually cannot be obtained on this basis; therefore, the "prescribed" adjustment should be considered only the first approximation, in the "line-up" procedure. The final adjustment of the LBO units should be verified and refined on the basis of actual return-loss measurements between the cable pair (and its associated LBO) and the repeater gain unit. The Test and Installer's Set for the AT-6 Repeater* contains arrangements to make such measurements.

Having achieved an optimum adjustment for the LBO units it remains only to set the "gain" switches to the appropriate value. Since the LBO units introduce some attenuation it will usually be best if the gain settings are made on the basis of overall net-loss measurements and thus determine the "net" gain of the repeater. Usually

*Test and Installer's Set for AT-6 Negative-Impedance Repeaters, E. L. Roback, Automatic Electric Technical Journal, July, 1961.

the gain of the repeater is taken to be the average of the readings obtained at 500, 1000, 1500, 2000 and 2500 c/s. Any marked differences between these readings would suggest trouble conditions on the cable facilities or in the repeater itself.

Conclusion

The AT-6 Negative-Impedance Repeater embodies the latest design techniques to achieve a reliable, economical, simple and small unit. The designer has been eminently successful in achieving these objectives, but unless the line facilities to which the repeater is to be applied also meet certain minimum standards, successful repeater operation cannot be achieved.

Signaling impairments due to the repeater must also be recognized and due allowances made for these effects.

M. J. Leach graduated from the University of Illinois in 1950, with the degree of B.S. in Electrical Engineering. He joined Automatic Electric that same year as a student in the training school. Following completion of the course, he was assigned to the Testing Bureau, Installation, Exchange Engineering, Process Engineering and then returned to the training school as an instructor in circuits. Next he was assigned to the Product Design Department of the Laboratories as a project engineer in the Power and Signalling. group. Now he is assigned to the Consulting Engineering Department of Automatic Electric Company as a staff transmission engineer.

SELF CONTAINED P-A-B-X SERVES 80 STATIONS

By R. V. Oldham and J. R. Wylie
Leich Electric Company

In recent years the application of business telephone systems has been broadened to include a greater proportion of P-A-B-X installations serving fewer than 100 lines. A somewhat greater subscriber turnover among users of these smaller systems, and the nature of the premises on which they are installed, require the switching equipment to be readily movable, attractively housed, and available on short notice. To provide these features for installations of more than 40 lines, Leich has added the 80A P-A-B-X to its line of common-control intercommunicating equipment, which includes larger systems individually engineered to the job, as well as the similar 40A P-A-B-X, introduced in 1958.

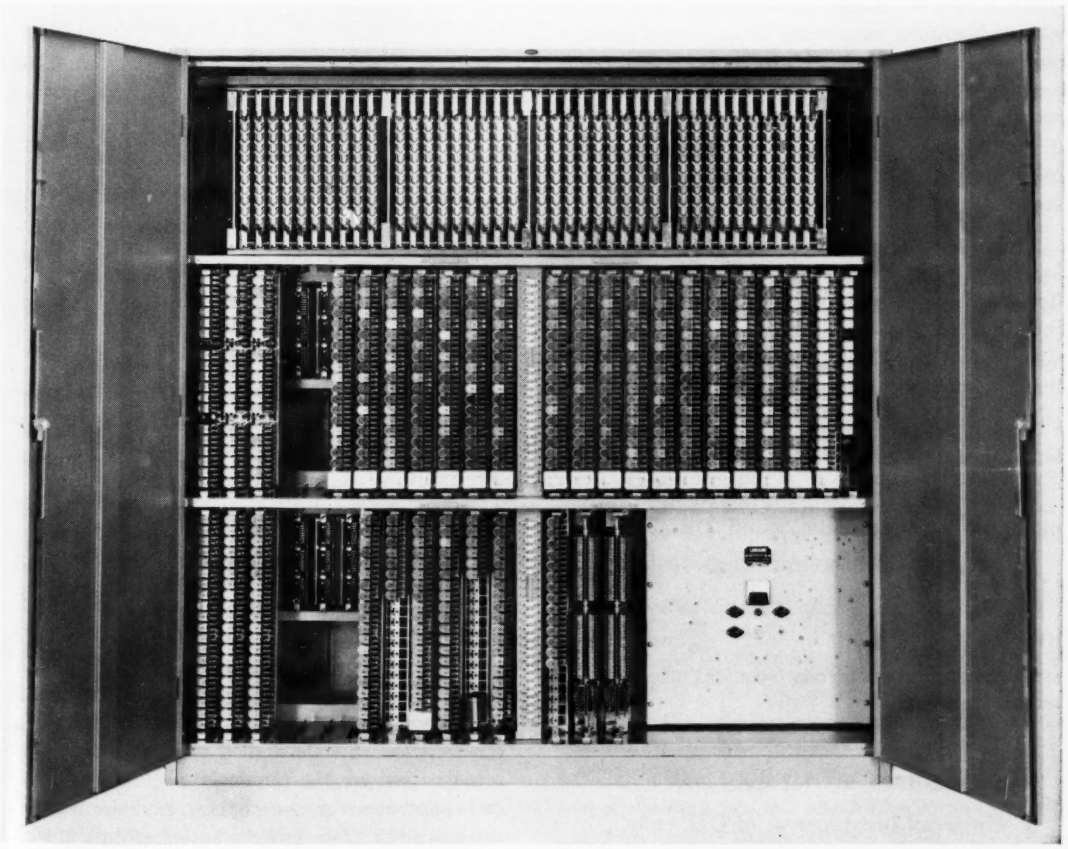


Figure 1. 80A P-A-B-X equipment cabinet, shown here with its swing-out center door panel removed. The modified crossbar switches unique to Leich equipment are mounted on the top shelf, the links and common control equipment below. Power is supplied by the transistor power unit at bottom right, which serves as either a battery eliminator or a battery charger.

General Description

The 80A P-A-B-X (Figure 1) has a capacity of 80 lines and 20 city (central office) trunks, and can handle up to 12 inside and up to 20 outside calls at the same time.

The trunks may be divided into two or three groups, to provide access to several central offices or to distant PBX and P-A-B-X systems. For purposes of trunk access, the stations may be assigned to any of three different classes:

Non-restricted—can make outgoing calls over any trunk group by dialing the access digit assigned to that group.

Partially restricted—can make outgoing calls over either or both optional trunk groups (e.g., to a distant P-A-B-X), but not to the primary city (central office) trunk group.

Fully restricted — cannot make any outgoing calls unless they are placed by the attendant.

Any line may be placed in any of the three classifications by simple strap connections on the terminals of its line circuit. A compact, handsome attendant's turret (Figure 2) provides for handling incoming calls, and for placing outgoing calls for parties at partially or fully restricted stations.

To provide the number of access codes required for the various special features available, station lines are numbered on a 3-digit basis — 21x through 28x; the digit "2" is absorbed. The assignment of first digits (which indicates some of the special services available) is as follows:

1. Initially arranged for repeated absorption, but can be used for future special service.

2. P-A-B-X stations (additional special features may be assigned to 29 and 20).

3. Future special service.

4. Third group of city (central office) or tie trunks (optional).

5. Second group of city (central office) or tie trunks (optional).

6. "Meet-me" conference service (optional).

7. Code-call service (optional).

8. Universal night answer of C.O. calls.

9. Outgoing C.O. calls (from non-restricted stations).

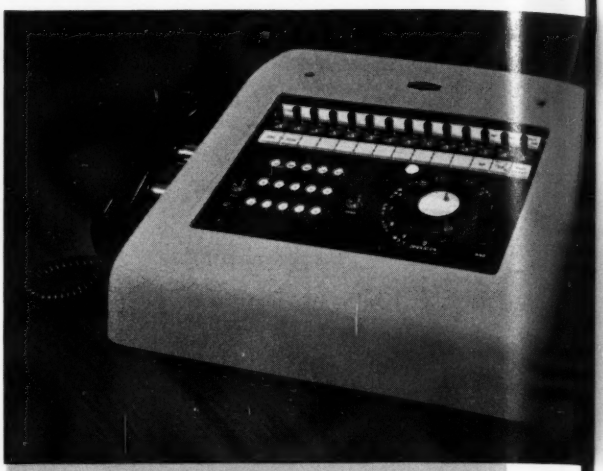


Figure 2. Standard attendant's turret supplied with the 80A P-A-B-X. The keyset permits very rapid extension of incoming calls; dial is used when placing outgoing calls for parties at restricted stations.

0. Information calls (to the attendant).

Until a digit assignment is put to actual use, the equipment is wired to return busy tone if that digit is dialed.

Other optional features include:

Two-way ringdown adapters for use with city trunks requiring this type of operation.

Executive service with automatic "busy-override."

Dictation control providing access to dial-controlled dictation equipment.

Rotary line-group selection, either by 3-digit station number or single-digit code.

Public-address-system adapter, which provides access to a PA system for paging.

Housing the Equipment

Ease of installation and removal is attained by housing the entire unit, including the transistor power supply and generators for ringing potential, dial tone and busy tone, in a 6′ x 6′ x 1′ 3″ cabinet. In the great majority of cases no additional equipment enclosure is needed. If storage battery operation is desired, the power supply can readily be connected to serve as a charger, and the batteries are placed in a low, louvered-steel cabinet finished to match the P-A-B-X. A high, narrow cabinet (Figure 3), which resembles an office wardrobe or

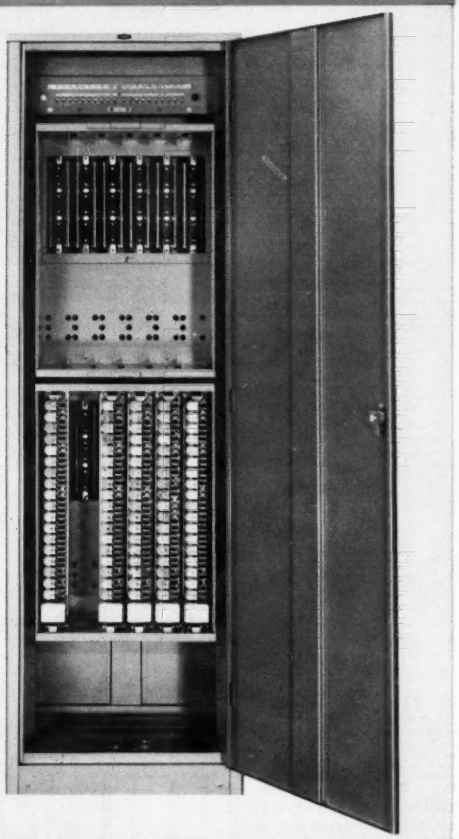


Figure 3. Auxiliary equipment cabinet allows a 19-inch relay rack to blend into office surroundings. Shown jacked into place are five relay bars for city (central office) trunks.

locker, encloses a 19-inch relay rack and can accommodate a one-third increase in the quantity of relay equipment if an exceptional number of optional services is provided. If the switchboard must be placed directly against a wall, it may be provided with a castered dolly to permit its being moved to gain access to the rear doors for servicing.

Selection Scheme

The basic elements of the selection scheme used in the 80A P-A-B-X are shown in Figure 4. Switch access to the lines is provided over stainless-steel line multiple bars, which pass horizontally through the finder and connector switches in 10 vertical rows of 40 bars each. (For clarity, the drawing shows only one of the four bars which provides a four-wire multiple for each line). Connection to a desired line is made by vertical motion of a "tens lift" and then of a "units lift", under control of common equipment. The finder operates automatically to connect the calling line to a "link", which receives the dialed information and acts in conjunction with common equipment to cause a connector to complete a path to the called line.

The four-wire bank multiple has a capacity of 100 outlets, 80 of which are assigned to station lines. The remaining 20 are available for optional equipment and for the bank appearance which each central-office trunk requires for consultation service. If more than 20 outlets are needed to provide the combination of optional services desired, bank points assigned to lines may be used, with a corresponding reduction in line capacity. The four-wire switches may be used interchangeably as finders or connectors, as well as in a third function peculiar to this type of equipment. In the latter assignment, a so-called "trunk switch" serves its associated central-office trunk as a finder on outgoing calls and as a connector on incoming traffic extended to a P-A-B-X station. The switch shelf (see Figure 1) provides space for 40 switches, while the equipment shelves will accommodate a total of 36 relay-mounting bars of the jack-in type.

Relays for the line and the power-failure-transfer circuits are separately mounted on bars which are cabled directly rather than by way of jacks; they may, however, be detached from the shelf for maintenance, if necessary, without interruption of service. Relay bars shipped with the standard switchboard provide service for 80 lines, using nine links and associated common control circuits. Additional links, up to a maximum of 12, may be ordered as accessory apparatus, as may a maximum of 20 city (central-office) trunks, and other optional features as desired.

Operation

Inside Calls

Lifting the handset at a P-A-B-X station extends its line to a link, as shown in Figure 5, through action of the conventional line circuit and of the finder guard, which signals an idle link selection control to choose one of its three associated links to serve the call. The finder guard notes the number of the calling line and directs

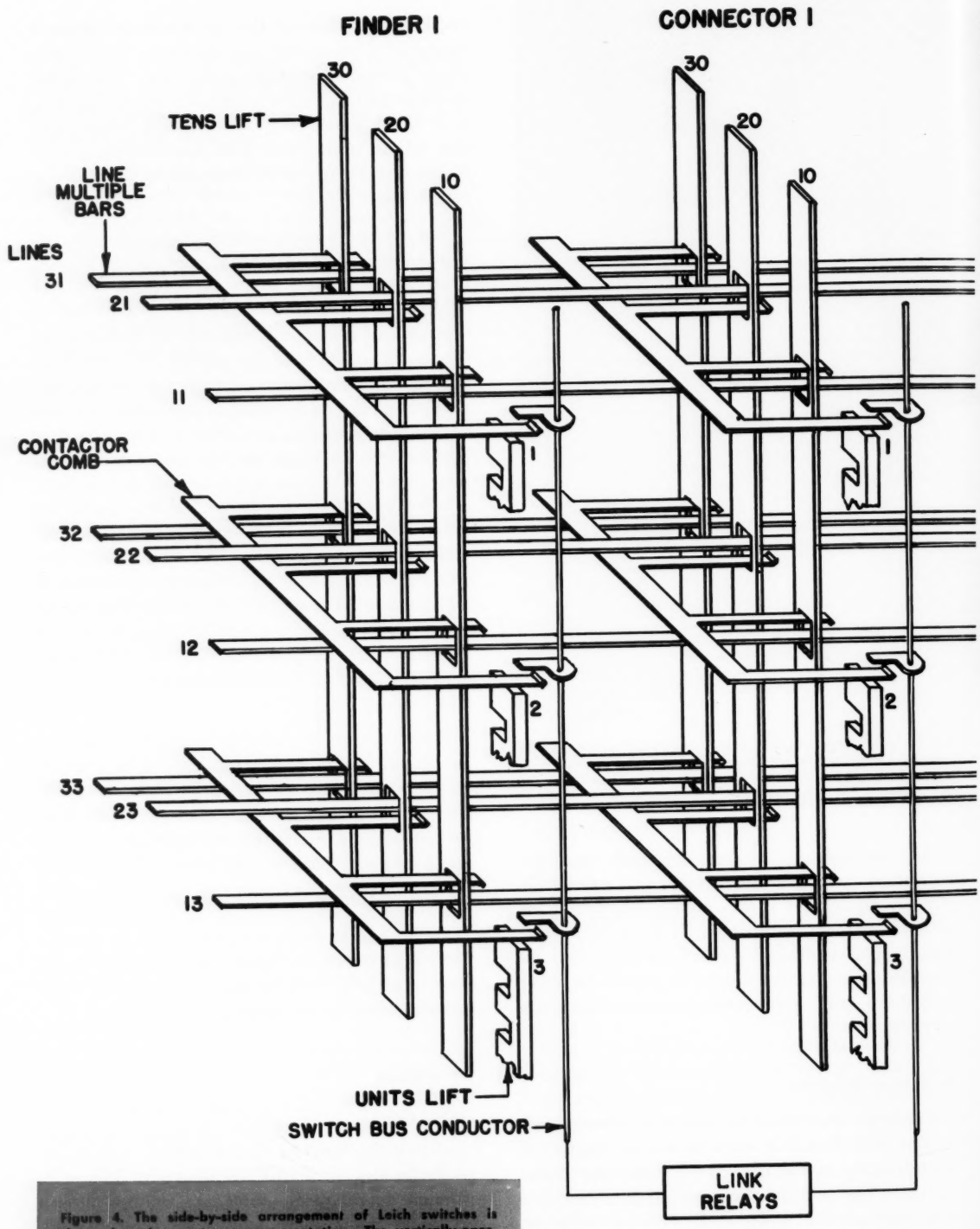


Figure 4. The side-by-side arrangement of Leich switches is shown here in a cutaway representation. The vertically-operating members are all referred to as "lifts", even though the odd-numbered ones operate downward because their armatures are at the base.

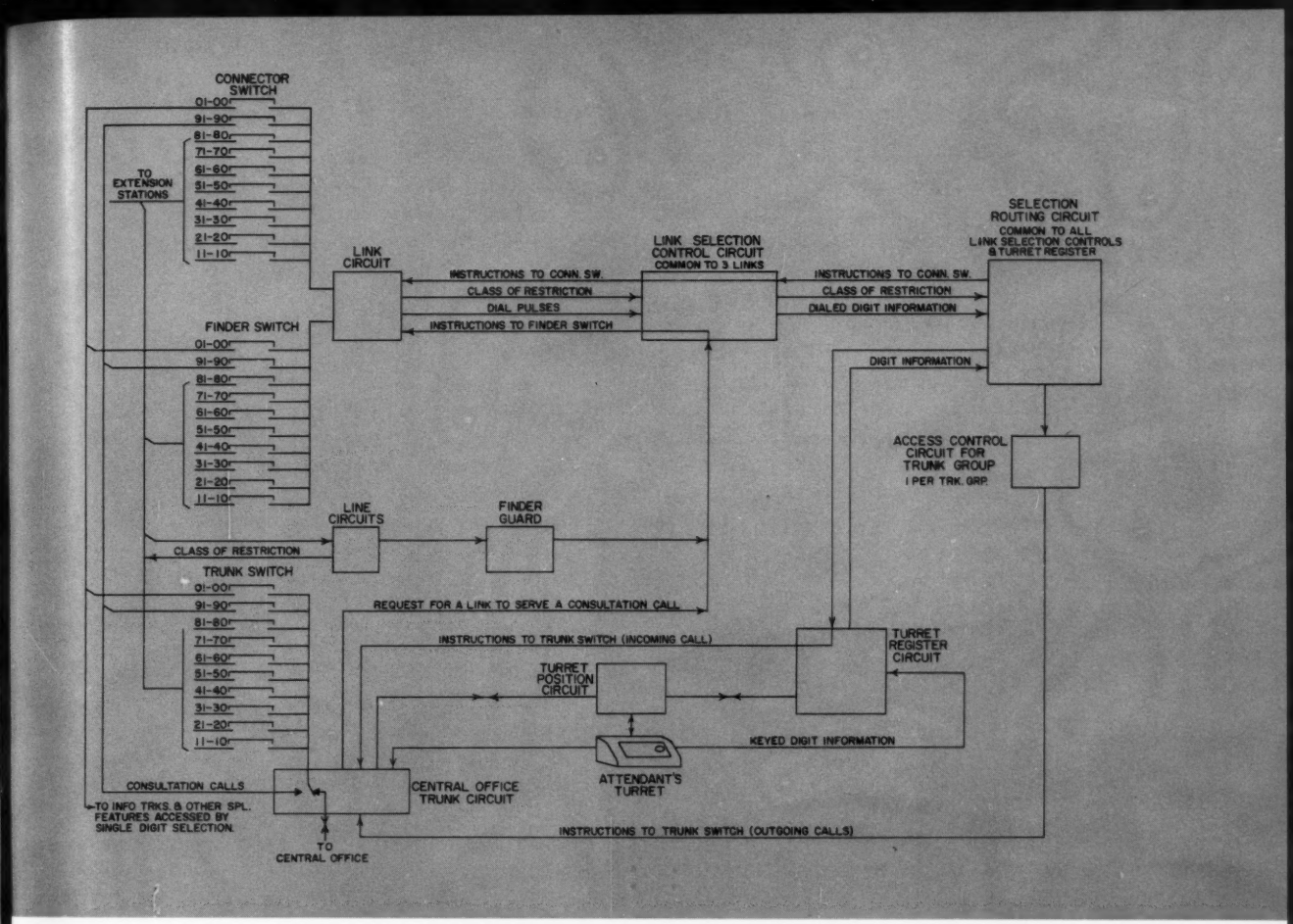


Figure 5. This block diagram of the switching and control circuits for the 80A P-A-B-X shows the manner in which switch operations are governed by common-control apparatus.

the finder switch associated with the chosen link to connect itself to that line. Making use of the fourth wire of the bank multiple, the line circuit provides information regarding the class of restriction applicable to the calling line. Once received by the link selection control via the link, these data are stored for future use.

Dial tone is connected to the line, and dial pulses are passed from the pulse receiving relay in the link to the link selection control, where they are counted and registered. During the interdigital time, the link selection control, where the information to the selection routing circuit to indicate the class of restriction applicable, the value of the digit dialed, and its position as first, second or third digit in the called number. Assuming 2 has been dialed as a first digit, the selection routing circuit acknowledges receipt of the information, so that the link selection control may release its counting and registering relays in anticipation of the digit to follow.

After the second digit has been dialed by the calling party, the link selection control again engages the selection routing circuit, which has been free in the meantime to serve other link selection controls or the register for the attendant's turret. Assuming 3 has been dialed as a second digit, the selection routing circuit recognizes this, and causes the connector switch associated with the calling link to prepare for a subsequent connection to one of the lines in the group 31 through 30. As shown in Figure 4, this is accomplished by the downward operation of tens lift 30 in the connector. By pushing the fourth finger of each of 40 contactor combs into contact with the stainless-steel line multiple bar of the corresponding conductor, it establishes a portion of a four-wire path to each line in the group.

Assuming "2" has been dialed as a third or units digit, the selection routing circuit is engaged for the third time by the link selection control, and causes the connector switch of the calling link to operate its units lift 2. This pushes the first, or front finger of the four contactor combs on the 2 level of the connector into contact with the respective conductors of the switch bus. The sets of contactor combs on the other nine levels do not complete a circuit, as all potential connections remain open at the contacts of the non-operated units lifts. On the 2 level, however, a four-wire connection is established to line 32, permitting the link to make a busy test. Regardless of whether the line is found idle or busy, the link now disengages itself from its link selection control, in order to permit that circuit to serve either of its other two associated links. The remaining actions necessary to complete the connection or to return busy tone to the calling party are carried out in the link, which is held for the duration of the call.

City (Central-Office) Trunk Calls

When a party at a non-restricted station desires to make a call to the central office, he lifts his handset to engage a link and link-selection control, receives dial tone, and dials 9. The link selection control forwards this information to the selection routing circuit, which recognizes the request for a trunk connection as coming from a station on a line permitted such service, and in turn engages the access control associated with the "9" group of trunks. This control (which also directs the rotation of outgoing calls over all trunks in its group to insure more equal usage) chooses the next idle trunk and causes the switch associated with it to connect itself to the calling line, as indicated in Figure 5. This done, the original connection through the finder switch and link is released to permit that circuit to serve other calls. The calling party receives central-office dial tone and proceeds to complete his connection by dialing the number of the desired central-office line.

An incoming call from the central office signals the attendant, who answers by operating the proper trunk key on a compact control turret, as shown in Figure 2. The call is extended to the desired station after the attendant has keyed the complete station number on the turret keyset. All three digits may be stored by the turret register, which engages the selection routing circuit, as shown in Figure 5. As soon as the latter is free, it accepts the stored digits one at a time, recognizes that they originate with the turret register, and instructs the trunk switch to operate a tens lift and then a units lift in accordance with the station number which was keyed. The position circuit makes a busy test of the called line and, finding it idle, causes the central-office trunk circuit to complete the connection and apply ringing potential to the line. The combination line and supervisory lamp associated with that trunk on the turret will then flash as a signal to the attendant that the called station is being rung. At this point she may restore the trunk key and answer other calls. When the called party answers, the supervisory lamp glows steadily.

The keyset permits very rapid extension of incoming calls, since the entire three-digit number can be keyed, the connection established in the switching equipment, and ringing potential applied to the line, in about the same time as would be required to dial one of the three digits in the conventional manner. A dial is provided on the turret for use where actual pulses are required, such as in originating calls to the central office, extending calls over tie trunks, or using the code call.

Consultation Service

To enable a party at a P-A-B-X station to consult someone at another station, while holding a central-office trunk on either an incoming or outgoing call, Consultation Service is provided. By dialing "1", or by depressing the handset hanger or cradle plunger of his telephone instrument for a moment, the P-A-B-X party may send a single pulse, which causes the central-office trunk circuit to request an idle link and link-selection control, as diagrammed in Figure 5. In response, the finder switch of an idle link is caused to be connected to the trunk over one of the bank-multiple outlets (91 through 90 and 01 through 00) which are not associated with station lines. The central-office connection is split off and held, while the consulting station party dials the number of the desired station and talks privately with the person to be consulted.

To return to the trunk connection, the person who originated the consultation call need only repeat the single pulse, either by dialing "1" or by

operating the cradle plunger. So long as the consulted party remains on the line, the originating party may switch the connection back and forth between the trunk and the consulted station as many times as required. (If desired, a conference wiring option may be connected to permit both P-A-B-X parties to converse over the trunk, yet talk privately between themselves whenever the one who originated the conference dials 1 or flashes, to split off and hold the central-office connection.)

Transfer Service

The party who originated a consultation call may decide that the consulted party is more competent to handle it, and may desire to transfer the call to him. This requires only that he so notify the latter party, who remains on the line while the originator of the consultation call restores his handset. The city (central-office) trunk circuit, recognizing this action as a request to transfer the call to the consulted station (which is still off-hook), first releases its switch lifts which have maintained the connection to the original line. The trunk circuit then directs the connector switch of the link used for consultation call to indicate the number of the line serving the consulted party. This information received, the trunk circuit directs its own switch to operate the corresponding pair of lifts and thus establish a new connection to the second line. Since its work is done, the consultation link is then signaled to release and, with the transfer complete, a conversation path is re-established to the party at the central office. In this manner the call can be transferred from one P-A-B-X station to another as many times as required.

Answering Incoming Calls at Night

The "universal night answer" feature permits any station, regardless of class of restriction, to be used to answer trunk calls when the incoming-call night signals are sounding. The answering party dials 8 to complete a connection to the calling trunk, and may extend the call to another station by means of the consultation and transfer features. Should anyone attempt to dial 8 at a time when no incoming call is waiting to be answered, or when the NIGHT key on the turret is not operated, he will receive busy tone.

An alternative, optional method of handling incoming calls at night is "predetermined night answer". With this arrangement, certain central-office trunk circuits are switched out of service, and their associated conductors to the central office are directly connected to preassigned stations when the attendant operates the NIGHT key. Incoming calls sound the ringer at the night-answer station for that trunk, and the call must be handled at that station alone, since it cannot be extended.

Power-Failure Transfer

In most installations, commercial power is sufficiently reliable to permit operation without storage batteries. To prevent isolation of the P-A-B-X during any power failures that may occur, a power-failure circuit assures continued service over certain trunks. This circuit operates in exactly the same manner as the predetermined night answer feature described above, but it switches the trunks in response to power failure rather than to operation of the NIGHT key.

Optional Trunk-Grouping Arrangements

Included with each standard 80A P-A-B-X are instructions for dividing the single group of city (central-office) trunks into two or three separate groups by the removal or addition of simple straps and jumpers. In addition, instructions and sketches show how to provide for a certain number of the trunks in the first group, the second group, or in both, to have first choice of outgoing traffic to the central office. The access controls associated with each group will then rotate outgoing calls over these first choice trunks until they all become busy, after which any additional outgoing traffic will be routed automatically to a second choice trunk, otherwise reserved for incoming service. As soon as a first choice trunk again becomes available, outgoing traffic is automatically routed to it. This arrangement is helpful in instances where no large rotary group is available at the central office, since it permits assigning the limited number of connector terminals that provide rotary service so that they are used only as second choice trunks, while the first choice trunks may be assigned to any available line circuit to handle one-way traffic originating at the P-A-B-X.

Auxiliary Attendant Turret

Optional equipment for the attendant includes an auxiliary turret, to which she may transfer

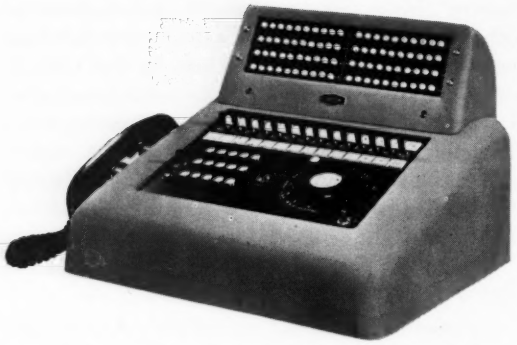


Figure 6. Busy lamp field shown mounted on the attendant's turret. A lighted lamp indicates each busy line whenever a trunk key, at panel top, is operated to answer an incoming call.

control of the even-numbered trunks during peak load periods so calls may be handled by an assistant, and a field of busy lamps for mounting on the turret, as shown in Figure 6. On the latter, a lamp lights to indicate each busy line whenever a trunk key is operated (as in answering an incoming central office call) or a button on the turret face is depressed.

Summary

Present-day trends in the application of business telephone service have created a demand for P-A-B-X systems which can be installed on short notice, and which can be easily modified for re-use at another location, if necessary. With its simple facilities for growth and for providing a wide variety of special services, the 80A P-A-B-X should go a long way toward meeting this demand.

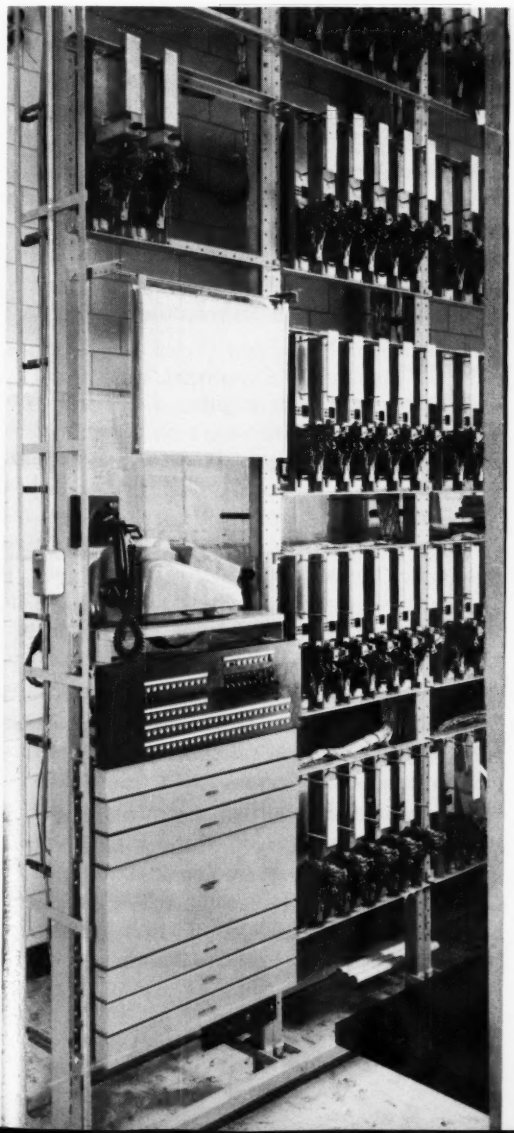
Robert V. Oldham, Jr., came to Leich Electric Company in 1947 from the Lorain (Ohio) Telephone Company. After assignments in Installation, Test, and Equipment Specifying, he was transferred in 1954 to the Circuit Development group. Here he has specialized in circuitry for terminal-per-station exchanges and for P-A-B-Xs of the finder-connector type. Promoted in 1961 to Supervisor of Circuit Development, Mr. Oldham is an Associate Member of AIEE.

James R. Wylie joined Leich Electric Company in 1954 after graduation from Wesleyan University and electrical engineering study at the University of Connecticut. Assigned to the Circuit Development group, he has specialized in station apparatus and central office equipment for paystation service, in addition to editing technical publications. Mr. Wylie is an Associate Member of AIEE, IRE, and the Acoustical Society of America.

THE NEW AUTOMATIC TRUNK ROUTINER

By J. P. Jallits
Automatic Electric Laboratories, Inc.

When long-distance or toll calls are extended manually, operators can judge when a trunk circuit is not functioning properly, and can report this to the maintenance force. Today, with the automatic switching of toll circuits and the widespread application of "extended area service" (EAS) some other means are needed for determining whether trunk circuits are in good working condition. To fill this need, Automatic Electric Laboratories has developed a new Automatic Trunk Routiner (see Figure 1) which is capable of routining any local inter-office and intertoll trunks that are accessed from a selector level.



The basic plan for automatically routining the trunks in office A is quite simple (see Figure 2). Each outgoing trunk in office A will be accessed from the Automatic Trunk Routiner in addition to its normal selector access; the trunks are routined simply by pulsing a test termination number over the trunk to reach a test line in the distant office.

This routiner was designed to automatically test either small or large quantities of trunks. Access to the tested trunks is made via Type 45 rotary switches, each accessing a maximum of 25 trunks. Type 45 rotary switches are also used as distributor switches, each accommodating a maximum of 25 "access switches". A maximum of 10 distributor switches may be provided. Thus, a routiner fully equipped with 10 distributor switches and 250 access switches may access a maximum of 6250 trunk circuits (this is, of course, contingent upon the degree to which the test termination numbers have been standardized in the area where the routiner is employed). The routiner is arranged to outpulse any one of 25 different numbers to reach a test-line termination. Each of these 25 numbers may have a maximum of 10 digits. When an intertoll trunk is being tested, the routiner automatically recognizes this fact and outpulses National Test Line Codes 102 and 103. In this case, no other test termination numbers are used.

Figure 1. This picture of the control panel shows the various selector keys and positions.

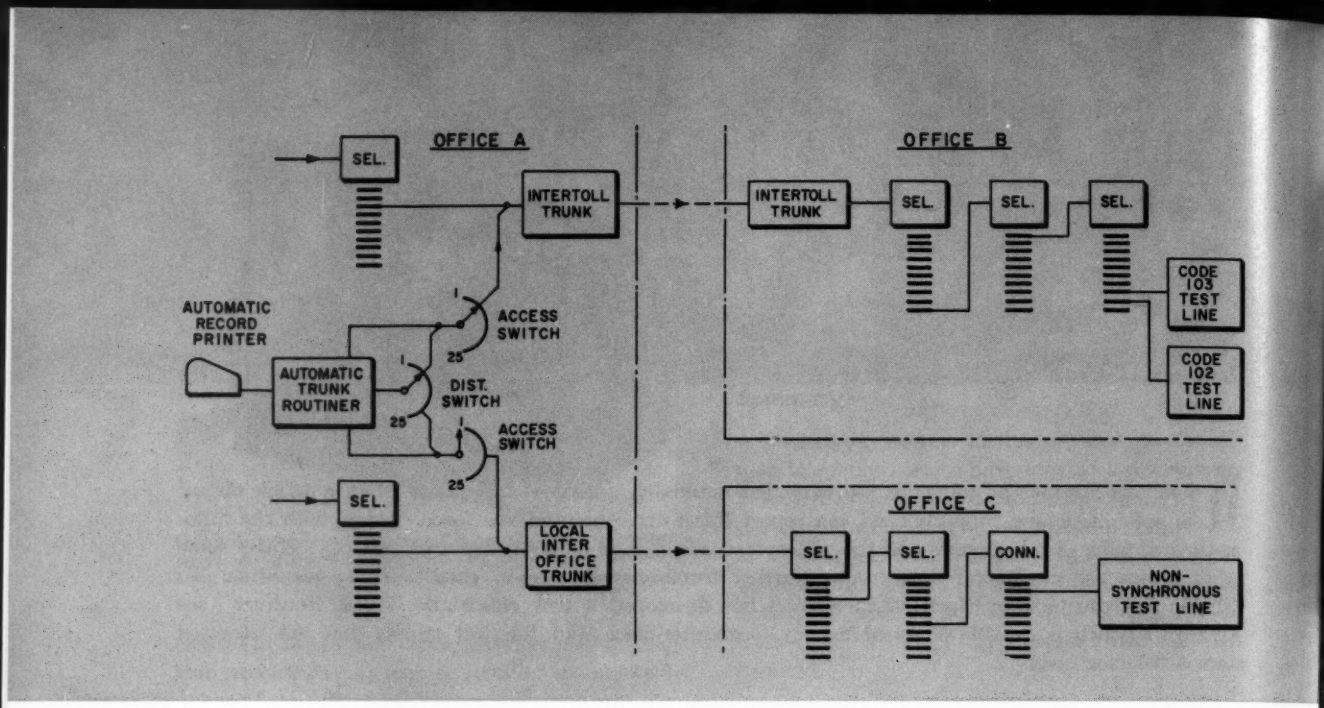


Figure 2. This schematic shows the basic plan for automatically routining the trunks in an office.

By appropriately strapping each distributor switch position the routiner is capable of functionally routining trunks having variations such as loop or simplex input pulsing, reverse battery and/or EC lead supervision, projected or returned C-lead ground, "stop-go" or "wink" dial start signal, trunks utilizing the National Codes 102 and 103, and other types of trunks (e.g. local interoffice) using different test codes.

Test-Line Terminations

When testing intertoll trunks, such as those between offices A and B, test code 103 is outpulsed to reach the supervisory test line; code 102 is used to reach the transmission test line. The routiner will make both of these tests with only one point of access.

When testing trunks other than intertoll, such as the local interoffice trunks between offices A and C, the preferred test-line termination is a "nonsynchronous" type which provides special supervisory signals with tone. This permits both supervisory and transmission path continuity tests to be made from one trunk access point. If such a test line cannot be provided, a test termination that gives special supervisory signals without tone may be used. Usually in crossbar or panel offices this is the test line that is available for supervisory tests; it is often called a "Synchronous Test Line". To make a transmission path continuity test on the outgoing trunk, a second point of access is used for pulsing to a test termination (with tone if desired).

At times, particularly in tandem offices, the only test line available for supervisory tests will give flash supervision (without tone). In this case a second access point of access to the trunk must be provided. This accesses a test line for making a transmission-path continuity test.

Operation

To adequately test outgoing dial trunks accessed from a selector level, a routiner must be capable of testing every step in the operation of the trunk circuit—seizure, C-lead condition, start dial signal, pulsing, answer supervision, etc. All these tests and others are provided by the new Automatic Trunk Routiner. An integral part of this routiner is an Automatic Digital Read-Out Printer, which records the trunk circuit that has failed a test, and the nature of the fault detected.

A routine may be conducted on trunks accessed with only one or any desired combination of distributor switches. This selection is made by operating keys on the control panel (see Figure 3) before starting the routiner.

If all trunks in the office are to be routined, all Group Selector keys are operated, followed by the START key. This causes the access equipment to select the first trunk of the first group. The trunk is immediately tested to determine whether

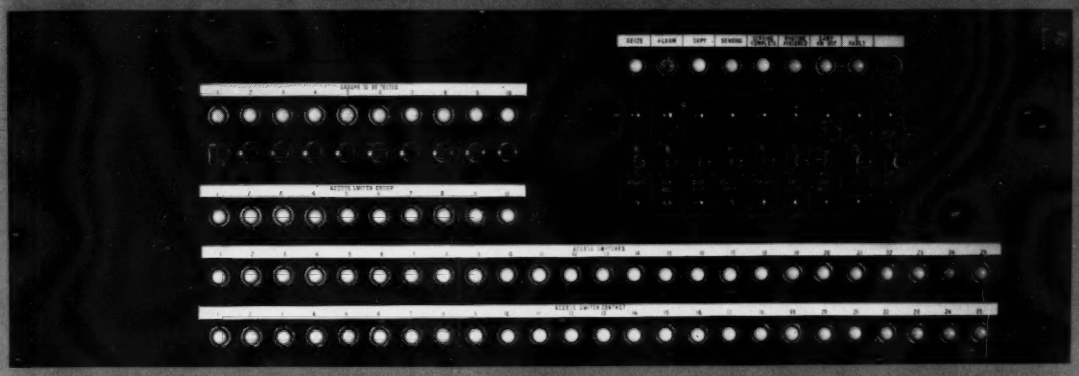


Figure 3. The Automatic Trunk Routiner can routine any local interoffice and intertoll trunks that are accessed from a selector level.

it is idle or busy. If the trunk is busy, the routiner does one of three things:

(1) It advances the access equipment to the next trunk circuit.

(2) If the busy control key is placed in its TIMED CAMP-ON position, the routiner will camp-on the busy trunk for a specified time interval before proceeding to the next one. If the trunk does not become idle within this timed interval, a printed record will be made of the busy trunk and the routiner will be automatically restarted.

(3) If the key is operated to the permanent CAMP-ON-BUSY position, a signal will be given when the routiner finds a trunk busy. This signal will continue until the trunk becomes idle or the routiner is advanced manually (by key operation) to the next trunk.

If the trunk is idle, it will be seized by loop-closure or in a simplex manner, depending on the type of trunk being tested. At this point, a test is made to determine the condition of the simplex or loop trunk leads. If the trunk fails to respond correctly to this seizure test, the trunk circuit number and a code number denoting such a failure will be recorded by the printer. An alarm will be sounded, but the routiner will not stop; it will continue its testing on the next trunk.

Where the trunk has responded correctly to the basic seizure test, the routiner goes on to test for the return of ground on the C-lead, or it forwards a C-lead ground ahead (if marked as such in the routiner). If it is expected that a C-lead ground will be returned by the trunk circuit, and no such ground is received, the routiner considers that this trunk has failed the C-lead test. The trunk number and the proper "failure code" are then recorded by the printer, and an alarm is sounded; the routiner does not stop, but goes on to test the next trunk.

If a trunk circuit gives a "stop-go" or "wink" dial start signal, these functions are also tested. On such trunks, we expect a transition from off-hook to on-hook supervision; if the final on-hook condition, in either case, is not returned after a specified time interval, the routiner recognizes this condition; the trunk number and the failure code are recorded. Once again an alarm is sounded and the routiner advances to test the next trunk.

If the trunk has correctly responded to the C-lead test and the dial start signal, the routiner proceeds to outpulse, directing the call to the distant-office test-line termination.

When a stop-dial condition or momentary interruptions occur in a grounded C-lead circuit while pulsing the test-termination number, the printer records this fact. Again an alarm is sounded and the routiner advances to the next trunk.

After the complete test-termination number has been outpulsed, the test-line circuit is seized at the distant office. The routiner is now conditioned to initiate a supervisory- and/or transmission-path continuity test.

The supervisory signals returned from the test termination are on a timed basis; i.e., the termina-

tion returns a distinct number of on-hook and off-hook signals within a specified time interval. The routiner, on the other hand, has its own timing circuit which synchronizes with that of the test termination. The routiner is now capable of timing and counting the number of off-hook signals occurring within the specified time interval.

If the supervisory signals are received slower or faster than normal, or if the test-line circuit fails to return any supervisory signals, the routiner identifies the fault, prints a record, sounds an alarm, and automatically advances to the next trunk.

If the accessed test-termination provides tone signals in addition to its supervisory signals, a transmission-path continuity test will be made simultaneously. In such cases, dial tone or low tone is generally returned during the off-hook supervisory periods. It is during this time period that the transmission-path continuity test is made. If the routiner fails to detect the tone, it will be recorded as a fault and, as above, an alarm will be sounded while the routiner continues to the next trunk.

In this manner all trunks are routined sequentially, and when the last trunk of the last selected group has been tested, a signal is given, indicating that testing has been completed.

The routiner control panel has supervisory lamps that continually advise the maintenance man as to the trunk being tested, and the progress of routining.

There is also a manual pre-set facility, which permits routining a specific trunk, or starting the sequence with a specific trunk.

If the REPEAT key is operated, the same trunk circuit will be routined continuously.

A STOP-ON-FAULT key is provided so that routining will stop when a fault is encountered. Using this key, the operator can control whether or not the fault is recorded by the printer.

Operation of the TWO-TESTS key causes the routiner to automatically test each circuit a second time. After this second test cycle, the next trunk circuit is automatically selected.

A talk and monitor circuit is provided to facilitate testing a particular trunk. When the routiner is set to CAMP-ON-BUSY, the monitor circuit may be used to tell whether trunks that test busy are actually in use.

Conclusion

The Automatic Trunk Routiner was designed to give telephone companies a device for conducting more efficient trunk maintenance programs. The routiner's testing speed is dependent upon (1) the number of outpulsed digits necessary to reach a test line termination, (2) the speed of the switching equipment in the distant office and (3) the response or type of test termination used.

It is estimated that the average holding time for each test call will be about 35 seconds. At this rate, the routiner will test approximately 100 trunks per hour.

Joseph P. Jallits graduated from Illinois Institute of Technology in 1950, with the degree of B.S. in Electrical Engineering. He joined Automatic Electric that same year as a student in the training school. Following completion of the course, he was assigned to Installation, Exchange Engineering, and the Testing Bureau. He is now assigned to the Telephone Switching Systems Department of the Laboratories as a project engineer, where he is presently doing development work on test equipment and automatic routiners. He is a member of the American Institute of Electrical Engineers.

DATA TRANSMISSION
Through Strowger Automatic Offices

By R. E. Stoffels
Automatic Electric Laboratories, Inc.

With the anticipated cutover of all TWX (teletypewriter exchange) service in the U. S. and Canada to automatic operation on Labor Day (September 3), 1962, and its subsequent operation over the nation-wide switched telephone network, the data-transmitting capabilities of this network will become extremely important.* This article is a report of a series of tests we conducted to determine the capabilities of Strowger Automatic equipment for "slow-speed" data transmission as herein defined.

In determining the capability of this equipment, or any equipment for transmitting such data it is important to remember that we cannot generalize and state the entire telephony plant is capable of doing this, or doing that. We must define the particular part of the telephone plant we are talking about. It is absolutely impossible to say that 100% of the telephone plant can do any single thing.**

The "capability" of a data transmission system is measured by determining its "error rate". Of course, the permissible rate may vary widely. A company simply ordering a part from one of its branches might be able to tolerate an error rate of one in a thousand; this would simply mean the occasional receipt of the wrong item, or the wrong number of items. A commercial bank, on the other hand, might require an error rate of less than one in a million, since large amounts of money may be involved.

Error rates encountered on data-transmission channels are normally expressed in "order of magnitude" figures (figures varying by a factor of 10). A rate of 10^{-5} means that one might expect 10^{-5} (or 0.00001) bits in error for each bit transmitted. This figure may, of course, be inverted, thus producing a figure of one error in 10^5 bits transmitted. (Because of the variation in test results one does not normally express results of this sort in numbers more accurate than order-of-magnitude.)

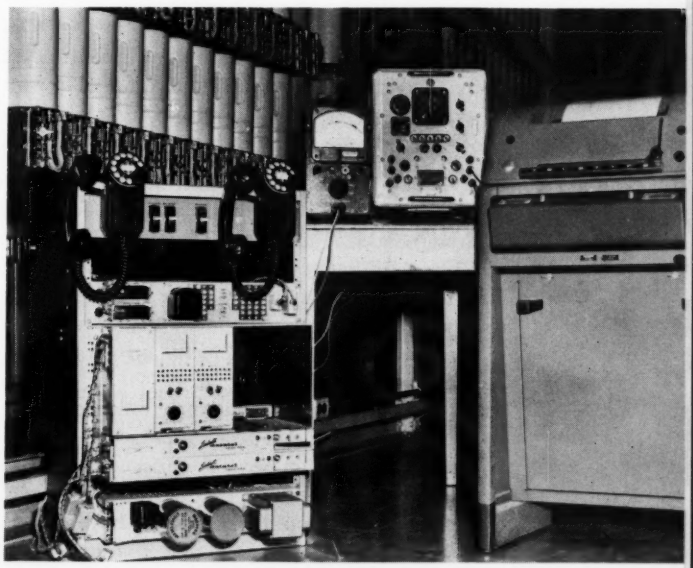


Figure 1. This test equipment was used.

"Error Rate" and "Noise"

The errors which are caused in the transmission of data are usually attributed to "noise"; this can variously mean the distant striking of light-

*Design Problems in Data Transmission Through Switched Telephone Networks, R. E. Stoffels, General Telephone Technical Journal, October, 1959.

**Capabilities of the Telephone Network For Data Transmission, A. Alexander, D. Nast, R. Gryb, Bell Systems Technical Journal, May, 1960.

ning, an inductive "spike" on one circuit coupled to another circuit, the momentary simultaneous connection of two circuits, or the momentary interruption of a connection because of a sudden shock or because of worn equipment.

In voice communication, noise is relatively unimportant—a few milliseconds chopped out of the middle of a word is usually not even noticeable. In data transmission, however, the loss of a few milliseconds can make a significant difference—for example, change a mark to a space, a space to a mark, or both. A burst of noise may be as long as several bits of information, and may have many times the amplitude. Since the data-transmitting equipment cannot overcome noise by "talking louder" or by repeating, stringent engineering practices must be followed in the design and maintenance of the telephone plant to be used for data transmission.

How the Tests were Conducted

It has been generally agreed by people working in the field of data transmission that the only way to satisfactorily prove the capability of a telephone system for transmitting data is to try it! Mathematical pictures of a system, based upon the laws of probability, do not always work for this type of problem.

A prime difficulty encountered, however, in any tests to determine error rate is the relatively long time required to conduct these tests. If a test is planned to determine whether the error rate on a particular channel is one in 10,000 or one in 1,000,000, then a million bits of information must be transmitted over and over again before one can be sure. And when an error *does* occur, who is to say that it was not caused by the test equipment? Consequently we cannot say that we have proved anything beyond the shadow of a doubt. We can only say that our results give several fairly good indications.

Our general testing procedure in all tests was essentially the same (see Figure 1). A test set which automatically generates the sentence "TEST THE QUICK BROWN FOX JUMPED OVER THE LAZY DOGS BACK 0123456789" was available, and the output of this set was fed (at a transmitting speed of 74.2 bits/sec, which is equivalent to 100 words per minute) to a unit of Lenkurt 23A telegraph carrier frequency-shift modulator equipment. Thus, the dc signals produced by the test were converted to voice-frequency tones — one tone representing a "mark" and the second tone representing a "space". (The frequencies used were 1955 cps $\pm$ 35 cps.) The output of this piece of telegraph carrier equipment was then fed through several lever keys to a telephone loop. By using the associated telephone and dial a connection could be dialed through the equipment under test to a second telephone loop (see Figure 2). This loop was connected (again, through several lever keys) to the demodulator portion of the Lenkurt telegraph carrier equipment, which reconverted the voice-frequency signals to dc signals, to drive a Teletype Model 28 page printer. The received message (line after line of the test message) was scanned visually for errors.

In the early tests, the transmitting level was set in the neighborhood of -10 dbm—and since little or no outside plant was used, the receiving level was not much lower. It soon became apparent, however, that this relatively high level, though technically correct, would drown out bursts of low-level noise, so that worse results

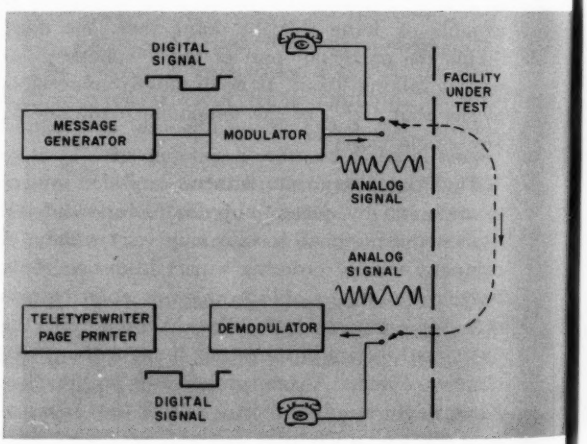


Figure 2. The test procedure.

would be obtained at lower levels. Therefore, in later tests the transmitting level was adjusted so the receive level would be approximately -36 dbm, which is slightly higher than the recommended minimum operating level of the demodulator.

In addition to the above-mentioned lever keys an additional one was included to permit back-to-back operation. In this way it was possible to loop the output of the modulator to the input of the demodulator, thus testing the accuracy of the

test equipment. Such back-to-back operation was utilized at least once a day during these tests.

At this same time the telegraph distortion into the page printer was measured, thus obtaining a figure for the equipment distortion. During actual tests the distortion into the page printer was again measured, thus obtaining a composite figure for the distortion added by both the equipment and the channel. The difference between these two figures was then listed as the distortion added by the channel.

Channel noise was measured with a W. E. Co. 2B Noise Measuring Set, using F1A weighting. So as not to have to make a large number of changes in the test equipment the "bridging" connection of this test set was used. In this mode of operation it is impossible to read anything below 22 dba.

We have based all Error Rate figures on bit error rates, since the bit is the smallest item of information transmitted. Other testing groups occasionally base their error rate on characters, but if this line of reasoning were pursued, the error rate might logically be based upon words, or even sentences! The bit error rate unquestionably proves more valuable to the engineer.

Four series of tests were conducted—two covering the telephone facilities that serve the Automatic Electric plant in Northlake, Illinois, and two involving the nearby network of the Middle States Telephone Co., serving Park Ridge and Des Plaines, Illinois. The summary data sheet (Figure 3) shows the results of these tests. The following comments should be made:

Tests No. 1 covered the 3000-line Automatic Electric P-A-X, which was 2-3 years old, well maintained, and had no outside plant. As can be seen, there were no errors received in this series of tests.

In tests No. 2, in the 20,000-line Strowger Automatic office, about 10-12 years old, at Des Plaines there was, once again, no outside plant included in the transmission path, but the office was an extremely busy one. Note that this time only a few errors were received — indicating that the equipment was very well maintained.

It might be mentioned, at this point, that in a poorly maintained office we might find two sources of error in the transmitted data:

First—actual impairment of the transmission circuit itself. For instance, a worn contacting member could conceivably result in circuit interruption, or even in double contacts. This is the sort of trouble probably encountered in tests No. 1 and 2; it would certainly become more apparent in a busy office, but would not be aggravated by transmission through outside plant.

Second—induced error. For example, a voltage transient which appears on one circuit due to the stepping or resetting of a switch may be coupled to the data transmission circuit through the capacitive coupling of the outside of the plant. Obviously, this sort of trouble would be aggravated by connection of the switching equipment to the outside plant. (This was demonstrated by tests No. 3.)

It should be stressed that when a facility under test includes both central office and outside plant we cannot summarily conclude that all errors received are due to induced errors rather than to poorly maintained equipment; both kinds of faults are possible.

Tests No. 3 were conducted from the Des Plaines central office, this time including outside plant in the transmission path so that errors would be due to a combination of circuit impairment and "induced" errors. The tests were broken down into three parts:

Part A included an exchange-grade cable pair to and from neighboring Park Ridge (four miles each way) and the Park Ridge central office, but no subscriber loop. The noise on this circuit (using F1A weighting) varied from 20 to 30 dba—a level which is usually considered marginal. During this test a large number of errors were received.

Part B again included the cable pairs to and from Park Ridge, but this time the circuit to Park Ridge was a very good toll trunk and the return path was any one of the cable pairs always available to local subscribers; again there was no subscriber loop in the circuit. The noise level on these circuits was usually less than 22 dba, and the error rate was much lower than before.

Part C included a cable pair to and from a remote part of the city, which was used for nothing other than local subscriber loops. Once again the noise level was always less than 22 dba, and the error rate was very low. (It may be interesting

Test	Test Site & Facility Under Test	Type of Equip.	Total Elapsed Time (Hrs.)	Transmission Level (dbm)	Attenuation (db)	Channel Noises (dba)	Characters Transmitted	Bits Transmitted	Total Bits in Error	Error Rate	Error Rate
I	Local 3000 Line P-A-X No Outside Plant	Strowger Step by Step	5	−9 to −12	0	—	180,100	1.37 x 10^6	0	0	1 Error in ∞ Bits
II	Des Plaines, Illinois 12,000 Line Office No Outside Plant	Strowger Step by Step	17	−4 to −22	0	—	601,500	4.51 x 10^6	3	.655 x 10^{-6}	1 Error in 1.5 x 10^6 Bits
III a	Des Plaines & Park Ridge, Illinois 20,000 Line Office 8 Mi. Non-Toll Grade Cable	Strowger Step by Step	4.67	−5 to −22	12	25 to 31	153,000	1.15 x 10^6	12	10.42 x 10^{-6}	1 Error in .09 x 10^6 Bits
III b	Des Plaines & Park Ridge, Illinois 20,000 Line Office 8 Mi. Toll Grade Cable	Strowger Step by Step	11	−23	13	<22 to 22	368,400	2.76 x 10^6	4	1.44 x 10^{-6}	1 Error in .69 x 10^6 Bits
III c	Des Plaines, Illinois 20,000 Line Office 3 Mi. Subscriber Loop (4)	Strowger Step by Step	10.08	−27	9	<22	360,600	2.7 x 10^6	5	1.85 x 10^{-6}	1 Error in .54 x 10^6 Bits
III b&c	Summation-Central Office Plus Outside Plant	Strowger Step by Step	21.08	−23 to −27	9 to 13	<22 to 28	629,000	5.46 x 10^6	9	1.64 x 10^{-6}	1 Error in .61 x 10^6 Bits
IV	Bell System Estebrook Exchange; Central Office Plus 8 to 12 Mi. Subscriber Loop	No. 1 Cross-bar	29.75	−5 to −26	9 to 18	<22	1,111,900	8.33 x 10^6	4	.48 x 10^{-6}	1 Error in 2.08 x 10^6 Bits

NOTES:

1. *All Tests Run at Transmission Speed of 74.2 Bits Per Second (100 words per minute).*
2. *All Tests Utilized a 7.5 Unit Baudot Code.*
3. *In all Tests Telegraph Distortion introduced by Channel was less than 57., except in one 2-hour Test Distortion was 11%. (One Error Received During this Test).*
4. *One 3.5 Hour Test During Severe Thunderstorm Activity (7 Errors Recv'd) Not Included Here.*

Figure 3. The Summary Data sheet shows the results of the tests made at Automatic Electric in Northlake, Illinois, and the Park Ridge and Des Plaines offices of the Middle States Telephone Company.

to note that during one of these tests there was severe local thunderstorm activity and during one stormy three-hour period seven errors were detected—an error rate of 7.6×10^{6}.)

Another type of exchange used extensively in this country is W. E. Co. Crossbar. So that we might have a better basis for evaluating the results we obtained from step-by-step equipment, we ran a comparable series of tests using crossbar. Because we were not able to determine the actual circuit makeup of these tests, however, only the "order of magnitude" of the results is valuable. These tests No. 4 used a transmission path to and from W. E. No. 1 crossbar exchanges; the noise level was again below 22 dba, and the received data was very low in error content.

Summary

The data collected during these tests show the following:

1. The error rate encountered in the Strowger Automatic central offices tested was approximately 1.64×10^{-6}. This is about one order of magnitude better than authorities predict for the results of the "average" telephone channel. (NOTE—We must at all times, in discussing such tests, be careful not to indiscriminately "lump together" all step-by-step equipment. For instance, some of the step-by-step equipment used outside the U.S.A. uses "dry" circuits for the talking paths, and as a result a comparatively great amount of contact noise is always present.)

2. The error rate encountered in the Bell System No 1 Crossbar offices tested $.48 \times 10^{-6}$. Once again, this is about one order of magnitude better than anticipated for the "average" channel. (The differences in test circuits preclude the drawing of direct comparisons between types of equipment.)

3. From the difference in results obtained between tests run with and without outside plant in the test circuit, it appears that the extent of this outside plant, and its quality, play an important part in error performance.

4. The level of transmission (as long as it is kept within design limits) does not appear to be an important factor in error performance.

5. When the transmission path includes aerial cable, electric storms greatly affect the quality of transmitted data.

These tests indicate that Strowger Automatic step-by-step offices are completely adequate for the type of data transmission that was the subject of this test. The error content of data transmitted through Strowger offices, though slightly higher than that of data transmitted through W.E. Co. No. 1 Crossbar offices, was of the same order of magnitude.

When step-by-step offices and the associated outside plant are designed and maintained in accordance with established standards their use for the transmission of digital data will prove eminently satisfactory.

Robert E. Stoffels first came to Automatic Electric in 1949 as a "Co-op" student while attending Northwestern University. After graduating with a B.S. in E.E. in 1952 he became active in the designing of Teletypewriter Switching Systems in the Laboratories. He served two years, 1955 to 1957, in the office of the Chief Signal Officer, U. S. Army. He returned to the Laboratories in 1957, and has been active in the design of data communication systems since that time. He is presently a group leader in the Product Design Department. Mr. Stoffels has had three patents issued by the U. S. Patent Office, and three additional patents are on file. He is a member of A.I.E.E., A.F.C.E.A., and Eta Kappa Nu. He represents the company on E.I.A. and C.C.I.T.T. committees.

TELETYPEWRITER SWITCHING *for a Police Department*

By R. C. Herzfeld
Automatic Electric Laboratories, Inc.

In the city of Chicago, all calls from citizens to the headquarters of the Police Department are received in a room called the Central Complaint Room. From this room calls are, in turn, transmitted to police cars by radio, and to some twenty districts through an "Operational" teletypewriter network. The teletypewriter operators select the district stations which are to receive each call. This is a two-way system, so all stations are equipped with "Send-and-Receive" machines. A somewhat parallel teletypewriter network is provided for "Administrative" comunications; this network is one-way (outgoing from the headquarters), so "Send Only" machines are provided (Figure 1). Complete switching equipment and controls for the combined communications system (see Figure 2) were designed and supplied by Automatic Electric.

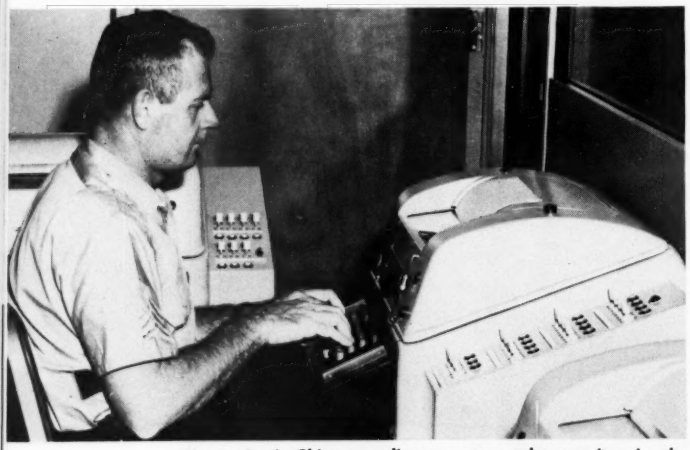


Figure 1. A Chicago policeman at a teletypewriter in the Central Complaint Room. The "Send and Receive" control panel for operational communication is to his right and the administrative "Send-Only" unit is to his left.

Communications activity is controlled from eight zones (which are not exactly equal to police areas in the city). Each zone includes the communications to a number of police stations, district stations, and area headquarters. Each of these outlying points is provided with two teleprinters, a Send-and-Receive for Operational (two-way) network and a Receive-Only printer for the Administrative network.

In the Complaint Room, each zone operator has two teletypewriters. For the Operational network, a Send-and-Receive machine is provided, equipped with a control panel with keys for selecting those printers in his zone which are to receive each specific message. For the Administrative network, a Send-Only machine is used, its control panel equipped with additional keys to select up to eight printers which are common to all zones. (For each Administrative zone, there is also a printer in the Press Room and one in the office of the Chief of Patrol Division; these printers receive all messages transmitted through the Administrative network). Finally, there is an Automatic Send-and-Receive (ASR) set for transmitting "broadcast" messages to all the above-mentioned outlying printers. To monitor traffic, the zone printers and the ASR set print page copy as they transmit.

The Administrative Network

A pair of wires is provided from grounded battery at the Complaint Rooom to each machine in this network; one is for polar signaling, the other for control. The receiving polar relay is connected directly to ground; the teletypewriter "marks" and "spaces" are represented by −130 v., and +130 v., respectively.

A zone operator wishing to transmit on the Administrative network makes his selection of one or more stations by operation of the associated lever key. As the connection is made, an

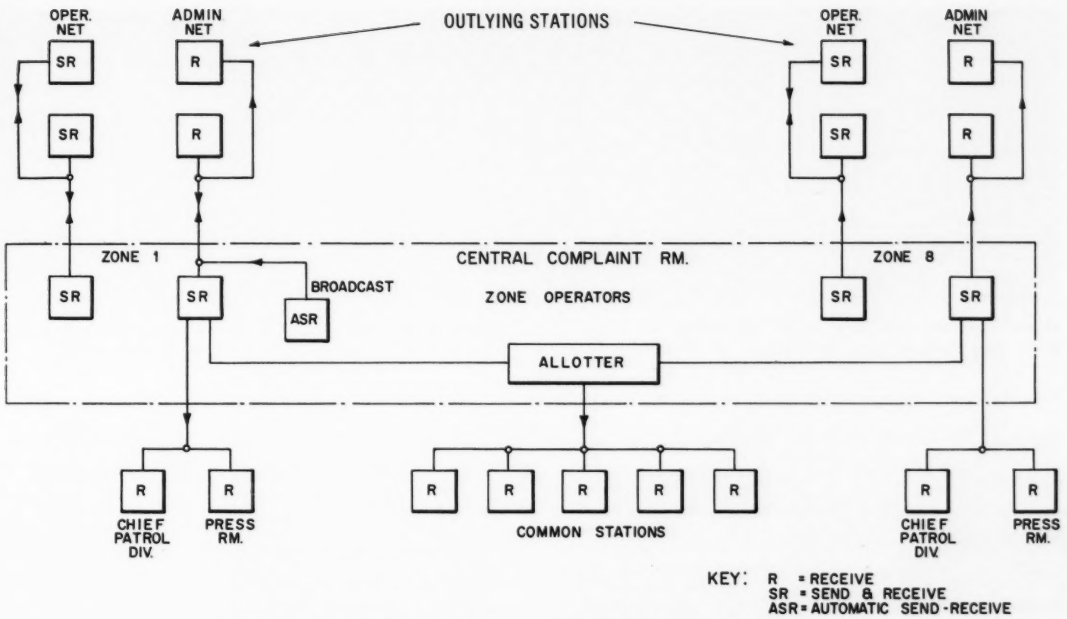


Figure 2. This diagram illustrates the communications between two of the eight communication zones in the system. There is a maximum of seven outlying stations in each zone.

associated lamp is lit from a normally closed "pulse-per-character" (PPC) contact on the distant printer, over the control wire and through the operated key to battery. When all stations are selected, the operator depresses a LINE-BREAK key, causing +130 v. to be transmitted to the signal line to prepare a circuit in the receiving machine. When marking (normal) energy is re-applied to the line, the motors of both the sending and receiving machines will start.

The operator may now transmit, and as each character is received by a distant printer, the associated lamp on the operator's panel flashes. This assures the operator that the message is actually being received; should any printer motor fail to start, the associated lamp will not flash even though its receiving polar relay follows the signal.

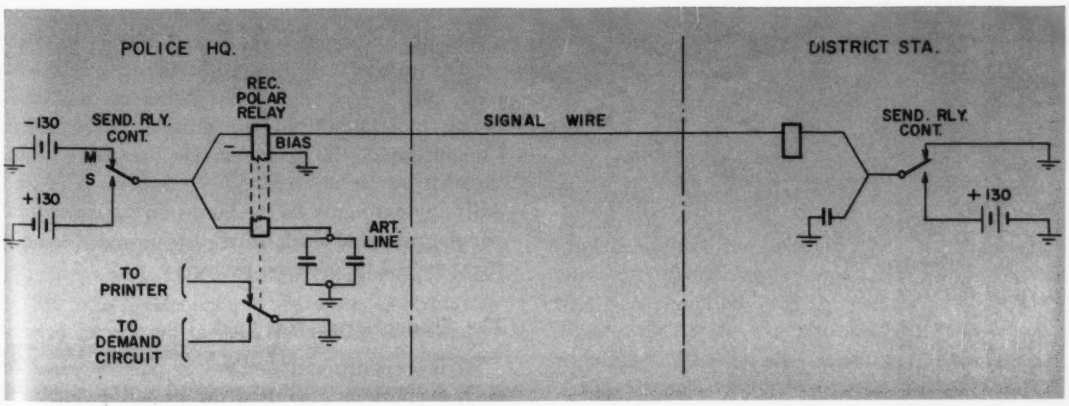


Figure 3. In the Half-Duplex Polarential circuit, the current through the line windings of the Receive relay (at left) causes opposing (and therefore cancelling) fluxes. This is true regardless of the position of the Send relay at headquarters. Marking bias is overcome only when the Send relay at the outlying station goes to "Space". The receiving relay (at right) is controlled by the direction of the current flow which responds to Send relay at headquarters.

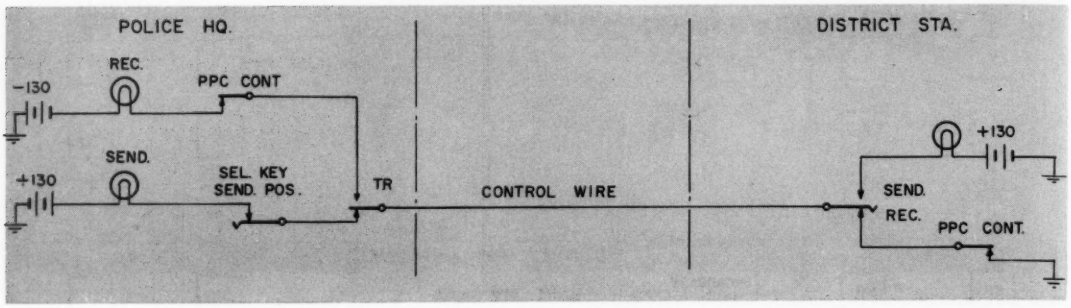
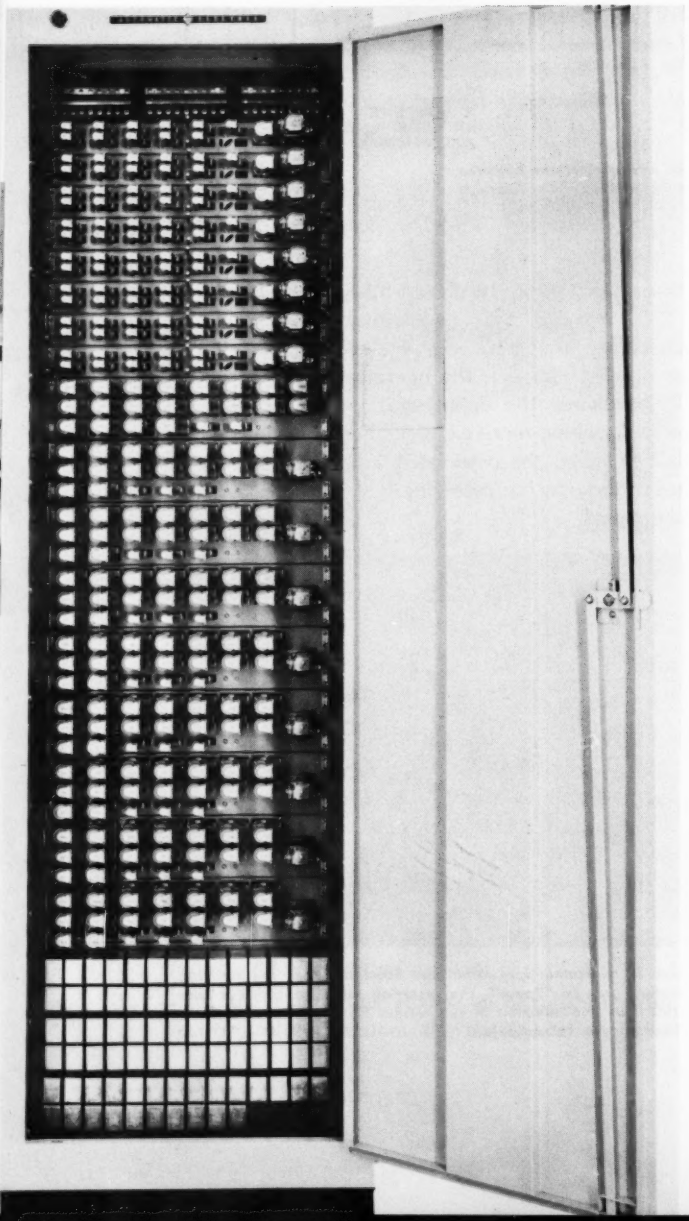


Figure 4. In this schematic circuit, the method of operating panel lamps can be seen. The position of Relay TR indicates seizure of the zone printer by the outlying station. Pulse-Per-Character (PPC) contacts cause the flashing of the lamps.

Figure 5. The Control equipment cabinet, with relay covers removed.



At the end of the message, the operator transmits the code, "(Figures), H." This code is detected on a code detector which is provided with every printer. This causes motors on both sending and receiving printers to stop. A timing circuit provides an audible alarm if the selection keys are not restored to normal shortly after the end of the message.

Selection of one or more of the common stations is also accomplished by operation of the proper keys, provided that the desired stations have not already been seized by another zone printer.

If a "Broadcast" message is to be sent, the operator first prepares the message tape, then operates a key on the ASR set. This action causes one lamp on each operator's panel to light. The lamp indicates that the ASR operator wishes to transmit from the ASR tape transmitter, and it serves as a warning that all other operators are to finish all transmission promptly and are not to start new messages. When all keys on all the printers in the Administrative network have been restored, a lamp lights on the ASR panel, indicating that transmission may begin. Conclusion of the message has the same effect as with other messages, and restoration of the ASR key extinguishes the lamps on the operators' panels. An audible alarm is also provided should this key not be restored promptly.

The Operational Network

In the operational network a pair of wires to each machine is also used for signaling and control, but in this case the signaling circuit has to pass signals in *both* directions (though not at the same time). This type of signaling (see

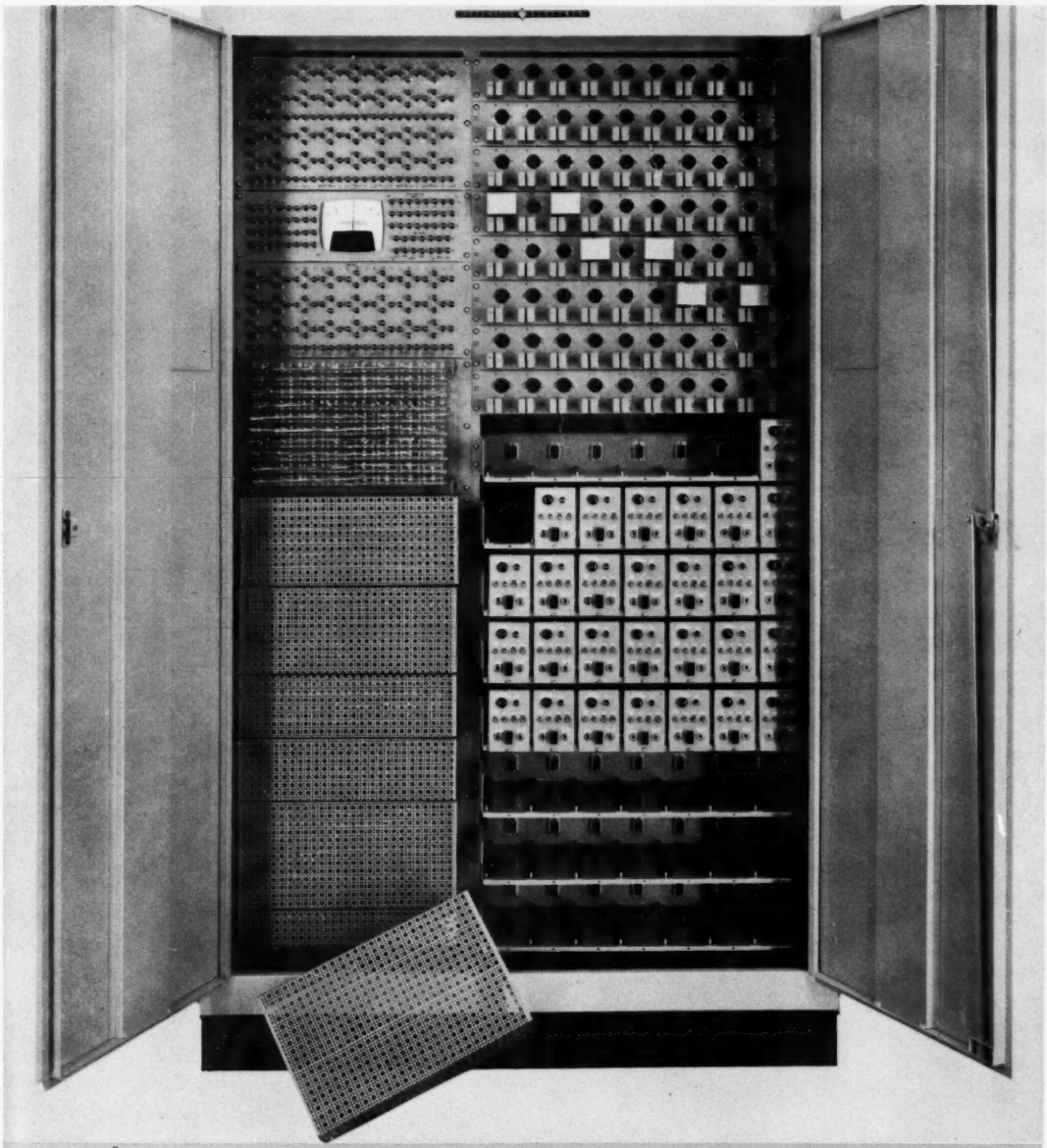


Figure 6. In this Signal Equipment Cabinet, the plug- in modules and polarized relays (six, in position) are shown.

Figure 3) is known as "Half-Duplex Polarential." Transmission from the Complaint Room is polar; in the other direction, however, a quantitative change in current is used to distinguish "mark" from "space." In the Complaint Room, the receiving polar relay bridges the line in such a way that it will not respond to signals sent by the zone operator. For this purpose one winding of the relay is connected to the line, the other to ground through an "artificial line" whose resistance and shunt capacitance are balanced with that of the actual line. A low marking bias is applied to a third winding and is overcome only when the bridge is unbalanced by application of ±130v. battery to the "space" contact of the send relay at the remote station.

Transmission by a zone operator is effected as on the Administrative network, except that since

the outlying stations are of the send-and-receive type the station operator's key must be in the "receive" position. This will cause the associated lamp to light on the zone operator's panel, as described above. The station operator is signaled, by the starting of his printer motor, that he is about to receive a message.

When the operator wishes to send a message, he moves his key (if the motor is *not* running) to the "transmit" position and depresses his LINE-BREAK key. If the zone printer is not busy sending or receiving from another station, it will be seized and its motor started. A lamp on the station operator's panel, then lights over the control wire to indicate that the zone printer has been seized and is ready to receive. If the zone printer is busy, the demanding station's request to transmit, which was effected by the line-break, is stored until the zone printer becomes idle.

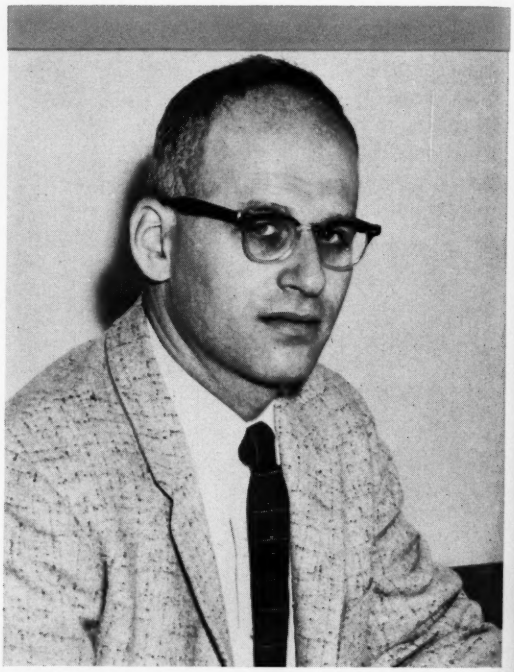
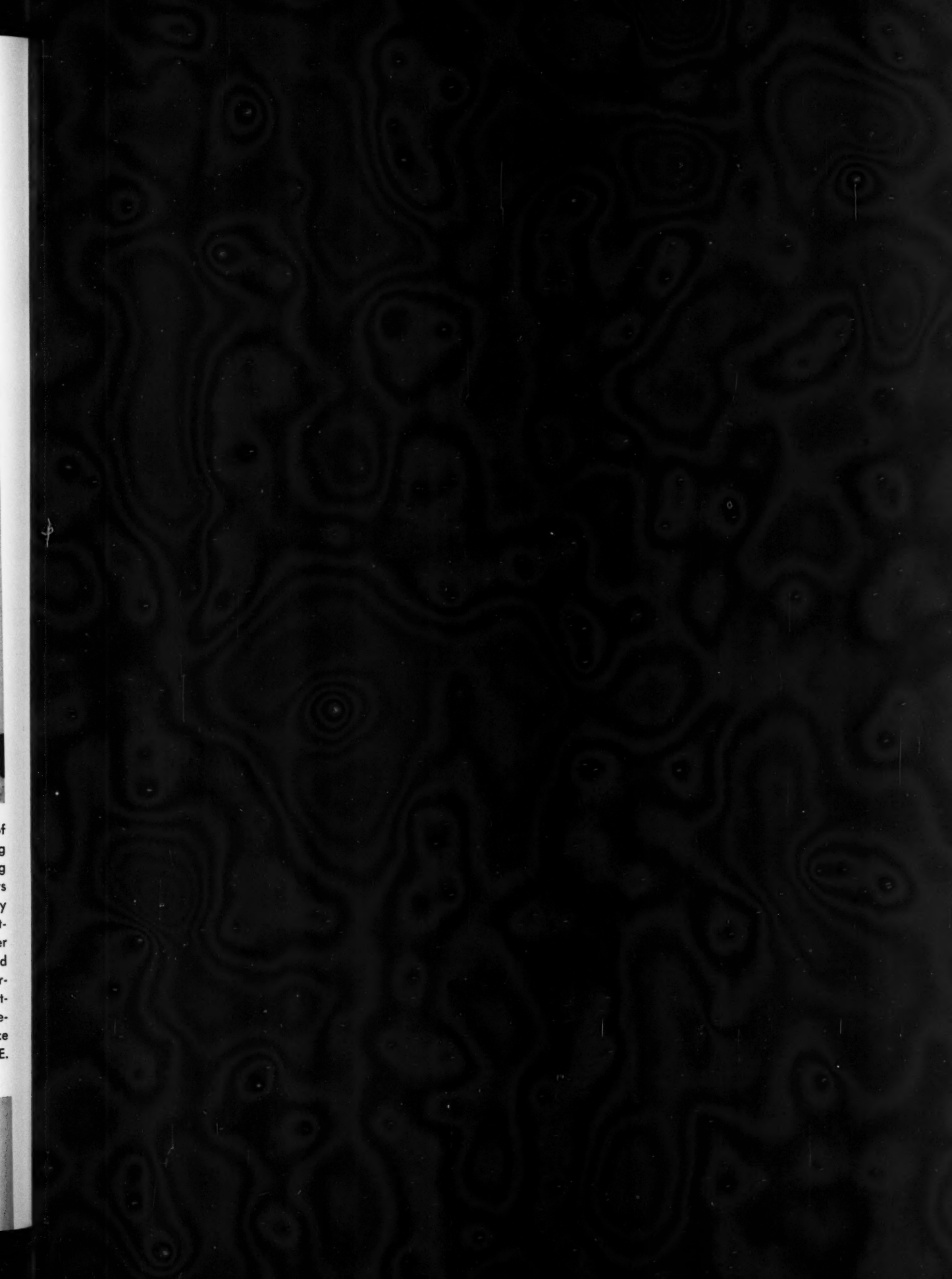
When the station operator has operated the above keys, circuitry in the Complaint Room causes operation of a "Demand" relay. This relay, which is operated from the "space" contact of the associated Receive Polar relay, (see Figure 5) remains operated until operation of the TR relay, which indicates seizure of the zone printer. The "Demand" relay causes operation of a "common start" relay which is associated with the printer. If the printer is idle, a rotary switch is stepped self-interruptedly until it finds the demanding station. When seizure is effected, the "Mark" contact of the Receive Polar relay is cut through to the printer, and lamps are lit (Figure 4) at both sending and receiving machines, indicating the seizure. Seizure of a "common" station in the Administrative network is effected by similar circuitry.

Among the features provided in this system is flexibility for expansion. Each zone operator's key panel contains extra keys and lamps which are fully wired. Relay equipment is provided and wired in for full expansion, and additional lines can be provided by adding polar relays and artificial lines which can be plugged into receptacles already provided and wired.

Equipment provided by Automatic Electric includes all key panels for the printers, relay control equipment, and power supplies.

The relay and power equipment is located in a small room adjacent to the operators' equipment. Control relays are mounted in the cabinet shown in Figure 5. All polar relays, artificial lines, and other line equipment are shown in Figure 6.

In police work, as in any military or semi-military organization, good communications are absolutely essential to effective operation. The teletypewriter networks described above, with their facilities for directing messages as desired, can thus make an important contribution to the effectiveness of police work in Chicago.



Robert C. Herzfeld studied at the University of Wisconsin and Lehigh University, graduating from Lehigh in June, 1948, with a B.S.E.E. Joining Automatic Electric in June, 1954, after five years with the Chicago and North Western Railway Company's communications and signal department, he has helped develop teletypewriter systems for the U. S. Army Signal Corps and holds a patent for Multipoint systems. He is currently supervising an Industrial Systems Department group which has designed the teletypewriter switching system for the Chicago Police Department. Mr. Herzfeld is a member of AIEE.